Ethylene

Crops

Identification of Petitioned Substance

Chemical Names:
ethylene

CAS Numbers:
74-85-1

Other Name:
Ethane, elayl, olefiant gas

Other Codes:
DOT #: UN 1962/UN 1938

Trade Names:
N/A

Supplemental Information

Ethylene Gas for the Induction of Flowering in Pineapple

Background:
Ethylene gas is included in the National List (7 CFR 205.601(k)) as a plant growth regulator, for the induction of pineapple flowering. In support of the sunset review of ethylene, the National Organic Standards Board (NOSB) crops committee has requested the following information:

1. Is there a continuing need for this material?
2. What is the current use pattern for this substance, and is it limited to a certain scale of production or are different size operations using it?
3. Do any new alternatives exist for this use for different scales of production?
4. Does continued allowance favor large scale production schemes and provide a disincentive for cooperative smaller scale production entities?

Responses to the Questions:

1. Is there a continuing need for this material?

The market for organic pineapple has reportedly increased over the past decade in both the US and EU. Some have attributed this growth in large part to the approval of the use of ethylene gas to induce flowering in organic pineapple production, which occurred in 2002 in the US and 2005 in the EU (Pay, 2009; Kleemann and Effenberger, 2010). Controlled flower induction allows for the best possible management of plantations and results in better production (Soler et al., 2006; PIP, 2006; Van de Poel et al., 2009b; Maruthasalam et al., 2010). Natural methods of "forcing" the pineapple to flower are known, however a review of the available literature suggests that those methods are not commonly used. Recent research on pineapple flower induction has been mainly focused on how to optimize the effectiveness of available agents, including ethylene, and how to make ethylene use affordable and practical for small organic producers. Therefore, it can be concluded that the use of ethylene gas remains important to organic pineapple production.

2. What is the current use pattern for this substance, and is it limited to a certain scale of production or are different size operations using it?

No specific usage data could be found for ethylene gas in organic pineapple production. Therefore, the current use pattern is not specifically known. However, the literature is clear that some type of forcing agent is used by most pineapple producers (conventional and organic), and the most frequently used commercial induction agents are ethephon (2-chloro-ethyl phosphonic acid) and ethylene gas (Van de Poel et al., 2009a). In general, ethylene gas is considered to be the most effective forcing agent available, but is not always used by small producers because of high cost and difficulty of application (Van de Poel et al., 2009a; Maruthasalam et al., 2010; da Cunha, 2005; PIP, 2007). Large producers of organic pineapples are likely using ethylene gas injected into water under pressure and applied with a boom sprayer over the plants (Van de Poel et al., 2009a). This process is usually initiated 7 to 15 months after planting, and sometimes application is repeated 2 to 3 days after the initial application. Many small organic producers likely cannot afford the expensive equipment needed to apply ethylene gas in this manner. It is unclear if small producers in the U.S. are using ethylene gas. However, there is evidence in the literature that small organic producers in East Africa are successfully applying ethylene gas using handheld small boom sprayers or applying activated charcoal enriched with ethylene directly into the center of the plants (Soler et al., 2006). The research on these techniques will be described in more detail in the next section.

3. Do any new alternatives exist for this use for different scales of production?

The commercially available treatments for floral induction of the pineapple worldwide have not changed since the 1999 TAP review for ethylene gas. These include ethephon, ethylene gas, acetylene, and acetylene-releasing calcium carbide. In conventional pineapple production, large producers tend to use ethylene gas or ethephon applied by boom sprayers over the whole plants, while small producers tend to use calcium carbide tablets applied to the center of each plant by hand (Bartholomew et al., 2003). Treatments that are less common but have been explored in the past include a-naphthalene acetic acid (NAA), b-naphthalene acetic acid (BNA), indole butyric acid (IBA), 2,4 dichlorophenoxyacetic acid (2,4-D), succinic acid, hydroxyethylhydrazine (HOH) and b-hydroxyethylhydrazine (BOH) (da Cunha, 2005; Bartholomew et al., 2003). Alternative natural methods to induce pineapple flowering include cold stress, smoke, exposure to ripe fruits, and selective tilling of the weeds and cutting back of trees in agroforestry systems. In regards to the latter method, the influx of light caused by trimming back vegetation near the pineapple plant is believed to be the causative agent in flower induction (UNCTAD, 2003, pg. 123). With the exception of cold stress, no current information could be found on the effectiveness or prevalence of any of these alternative natural methods.

No new alternatives for ethylene gas for different scales of production have been identified. However, there have been recent developments in alternative techniques for small producers to use ethylene gas and cold stress for the induction of pineapple flowering. This research is described below:

New Methods to Apply Ethylene

Small device handled by a single operator: Researchers at the French Agricultural Research Centre for International Development (CIRAD) developed a technique for small pineapple producers in West Africa that enables the application of gaseous ethylene with only minimal equipment (Soler et al., 2006). This technique is a scaled down version of the technique used by large producers. The system involves the use of a double hose mounted on a tractor attached to a double nozzle applicator that can be held by a single operator. This allows for the treatment of a double pineapple row while the tractor remains outside of the treatment plot. The necessary equipment includes: tractor, small boom sprayer (600 to 1000 L), access to bottled ethylene, the ethylene injector, and activated charcoal. The pumping system should allow constant recirculation of the water/activated charcoal solution toward the tank and must have an appropriate pressure regulator. An ethylene injection device is required to allow gas to be injected into the water in very small bubbles. The current pattern of use for this system in organic pineapple production is unknown.

Dry activated charcoal enriched with ethylene: Researchers at CIRAD/France and the Gembloux Agricultural University (FUSAGx/Belgium) developed another technique for small pineapple producers in West Africa based on the fact that ethylene is extremely efficient for floral induction when it is placed directly in the center of the plant and that activated charcoal has the capability to fix gases (Soler et al., 2006; PIP, 2006; PIP, 2007). The technique involves the injection of ethylene into activated charcoal which is then applied to the plants. In order to enrich the activated charcoal, it is placed in a plastic bag or other container under vacuum pressure. Pure ethylene is then injected into the bag and stays in contact with the activated charcoal for 3 minutes under atmospheric pressure. The cycle is repeated. This enrichment process requires: a vacuum pump, a bottle of ethylene with a regulator, an adapted airtight container, a gauge and tubes, valves, fittings, and filters. The enriched activated charcoal is applied directly to the center of the plants dry or suspended in water. Dry treatment with granules or powder is used when enough water is already present in the heart of the plants whereas wet application is used when no water is present. Several trials [funded by the European Pesticides Initiative Programme (PIP)] have studied this technique on plantations in Cameroon, Togo, and Ghana since 2005. Results from those trials have shown that this technique makes it possible to induce flowering in approximately 90% of treated pineapple plants 6 to 8 weeks following a single treatment (PIP, 2006). In the case of using wet application, a second application three days later tended to increase the chance of success to close to 100%. Results for two specific trials reported by Soler et al. (2006) support these conclusions. In one trial conducted on a plantation in Cameroon, a range between 80 and 90% of plants flowered following a single application of activated charcoal containing 6% ethylene. The results were similar for both dry powder application and mixed with water. In another experiment conducted on a plantation in Martinique, forcing with one application of a water suspension containing activated charcoal enriched with 1 or 2% ethylene resulted in between 90 and 100% of plants flowered in all groups with the exception of one group having only 76%. Comparison was made to the standard ethephon treatment (Ethrel + urea in water) which resulted in 97% of plants flowered. Soler et al. (2006) concluded that further studies are needed to develop a commercial product (activated charcoal enriched with ethylene) that is stable and can easily be used by small producers. A different ethylene-releasing agent was mentioned by Soler et al. (2006) as being very efficient in forcing pineapple to flower: Ethylene Clathrate by Air Liquide. However, Soler et al. (2006) state that this product could not be developed commercially because its only use was for pineapple forcing. As of 2007, the PIP was working to establish enrichment workshops in Cameroon, Ghana, and Togo in order to supply small producers with ethylene-enriched activated charcoal (PIP, 2007).

An online search shows one company that claims to sell enriched activated charcoal for flower induction treatment. TIFBio is a company based in Brussels, Belgium with the following claim on their website: "Our mission statement is to offer to pineapple producers full access to the new flower Induction technique developed by CIRAD and FUSAGx researchers for the Pesticide Initiative Program (PIP) of the COLEACP." (TIFBio). This company claims to sell enriched activated charcoal or the equipment needed for producers to perform the enrichment process themselves. They also offer training on this technique. The products are not for sale directly on their website, but an email address is provided to request further information. The current pattern of use for this system in organic pineapple production is unknown.

<u>Zeothene (zeolite containing ethylene gas) and ethylene dissolved in water applied to the central cup of the plant:</u> Researchers at the Katholieke Universiteit Leuven (Catholic University Leuven) in Belgium developed a novel pineapple flower induction agent called zeothene (also known as "ethylene pills") (Van de Poel, 2009a). This agent was mainly developed for small producers as it requires application by hand. Zeothenes are zeolite pearls which contain ethylene gas which is released upon contact with water. The weight of each zeothene pill is approximately 13.5 mg and it contains about 0.7 mL of pure ethylene gas. The pills (3–4) are dropped into the central cup of each plant where they come in contact with standing water. A trial was conducted at a commercial pineapple plantation in Ecuador that compared the efficiency of flower induction in the MD-2 hybrid pineapple cultivar with three different concentrations of zeothenes, ethephon, ethylene gas field application, and three different concentrations of ethylene gas dissolved in water (with and without activated charcoal). Each of the treatments was applied directly to the central cup of the plants, with the exception of the commercial ethylene gas field application in which the entire plants were sprayed with a mixture containing activated charcoal. Each treatment was applied 8–9 months after planting to 100 plants and was repeated three times. The percentage of plants in the same flowering stage 73 days after induction was measured for each treatment. The results showed that zeothene and ethylene dissolved in water (applied to the central cup of the plant) were more effective at inducing homogenous flowering than both ethephon and ethylene gas field application. The percentage of plants in the same flowering stage (3^{rd} flower) was 92.7% for zeothene treatments and ranged from 83.0–95.0% for ethylene gas dissolved in water. Surprisingly, the percentage was highest for the lowest concentration of ethylene dissolved in water (0.195 g/L), and the presence of activated charcoal did not

significantly affect the results at that dose level. At 73 days after induction, plants treated with ethephon were still in the 2nd flower stage and the homogeneity percentage was only 82.6%. The commercial field application with ethylene gas resulted in a homogeneity percentage of only 78.4% (3rd flower stage) which was significantly less ($p < 0.05$) than the results for both zeothene and the lowest dose of ethylene dissolved in water. As an additional experiment, several different concentrations of activated charcoal were tested in flasks to determine the optimal concentration to stimulate ethylene gas absorption. The results showed that only very high concentrations (5%) were effective at stimulating ethylene gas absorption. In typical commercial field applications of ethylene gas, activated charcoal is included in the carrier water solution at a concentration of only 0.286%. The results from this study suggest that concentration provides no advantage over plain water in the induction of pineapple flowering. Furthermore, this study demonstrates the higher flower induction efficiency of central cup applications over whole plant treatments. The current pattern of use for central cup applications of ethylene dissolved in water in organic pineapple production is unknown. No products have been identified with the name or description of "zeothene," "ethylene pills," or "zeolite containing ethylene."

Refined Methods for Using Cold Treatments

Researchers at the National Chung Hsing University in Taiwan conducted an experiment to determine the effectiveness of ice and ice water treatments on the production of ethylene in the lab as well as flowering in the field using the 'Tainon 17' pineapple cultivar (highly sensitive to natural flowering during cool winter months) (Maruthasalam, 2010). This method was of interest to the researchers as an alternative to ethylene gas for small organic producers. The authors mention that although anecdotal comments indicate that cold water has been used by organic pineapple producers to induce flowering, no recent published studies on the topic were found. In the laboratory experiment, the researchers placed 500 g of ice crystals on the rosettes of 12- month old greenhouse pineapple plants and then measured the ethylene gas production by excised tissues of the shoot apex or basal white portion of a ''D'' leaf (the excised tissues were exposed to cycloheximide in order to prevent the interference of wound-induced ethylene production). Results showed that ethylene production was greater in the apical tissue than in the "D" leaf bases, and production from ice-treated apical tissue was twice that of control apical tissue only 4 hours after excision. This prompted the researchers to study the effects of ice treatments in the field.

The field experiments were conducted in Taiwan during the 2006–2007 and 2007–2008 growing seasons on 11-month old plants. Treatments were completed in late October. In the first growing year, two different cold treatments were compared with control (25ºC water) and calcium carbide treatments. For the ice treatment, 500 g of ice crystals in nylon mesh were placed in the center leaf rosette of plants once or twice (at 24 hr intervals). For the cold water treatment, about 500 mL of ice water was poured directly on the rosettes once or twice (at 24 hr intervals). The results from this first experiment showed that 1–2 ice treatments neither promoted nor inhibited induction of flowering, but appeared to increase the plants' sensitivity to natural flowering in the coming winter months. The plants treated with calcium carbide were 100% flowered by mid-December, while those treated with ice or ice water did not begin flowering until the end of February with 100% flowering achieved in April. Based on these results, the cold treatments were increased for the second year. Plants were treated 3 or 4 times with 500 g to 2 kg of ice crystals or 500 mL of ice water at 24 hr intervals starting in mid-October. Calcium carbide, ethephon and control water (25 ºC) treatments were also conducted. The results showed that four applications of ice or ice water were comparable in efficacy to calcium carbide and ethephon treatments, although flowering was delayed by 3–4 weeks. A possible explanation for the delay is that bud development following cold stress is a cumulative effect within the plant while application of ethylene or acetylene (via ethephon or calcium carbide) results in a direct effect. Surprisingly, four applications of ice water (500 mL) were more efficient at inducing flowering than four applications of 500 g of ice. Furthermore, the results for four treatments with ice water were about equal to the results for four treatments with 2 kg of ice. The current use pattern for cold treatments to induce flowering in organic pineapple production is unknown.

4. Does continued allowance favor large scale production schemes and provide a disincentive for cooperative smaller scale production entities?

As mentioned in the response to Question 2, small scale organic pineapple production entities likely cannot afford the expensive equipment needed for whole plant application of ethylene gas in large fields (da Cunha, 2005; PIP, 2007). However, no direct evidence has been found in the available information that allowance of ethylene gas for use in organic farming is placing small-scale producers at a disadvantage. There is evidence that small organic producers outside of the U.S. have adapted modified techniques to apply ethylene gas, such as small handheld boom sprayers or manual application of activated charcoal enriched with ethylene or ethylene dissolved in water. It is unknown if small organic pineapple producers in the U.S. are employing similar techniques. For small organic pineapple producers that cannot use ethylene at all, repeated treatments with ice or ice water have been shown to be effective at flower induction in sensitive cultivars. Therefore, it can be assumed that the allowance of ethylene gas does not provide a significant disincentive for cooperative smaller scale production entities. However, due to a lack of specific data on how many small organic producers are able to survive in the current market, this cannot be known for certain.

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