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RESEARCH NEWSLETTER

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Potential Technologies to Reduce Ethylene Injury in Tulips

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As the 2008 season unfolds, exporters and growers will be keeping a close eye on *Fusarium* infection in tulip stocks. Everyone is aware that *Fusarium* infected tulip bulbs produce ethylene (or, more accurately, the strains of the *Fusarium* fungus that infects tulips produce ethylene the tulip bulb tissue itself does not), and that one of the major challenges confronting the entire industry is to develop ways to control this problem. As with most complex agricultural problems, the ultimate solution will probably involve many levels, including changes in farming practice, changes in chemical use, changes in cultivar selection (or new breeding efforts), changes in lifting and processing procedures, changes in storage and shipping procedures, and, in North America, changes in storage and handling procedures.

It is beyond the scope of this article, indeed, beyond my expertise, to address each of these issues. What I would like to do in this issue of the *Research Newsletter* is to review some of the technologies that are available or soon might be available for control of ethylene injury in tulip bulbs. If we assume that ethylene is going to be present in given lots of bulbs, or in a container during export, what will be some of the possible means to reduce its concentration, or otherwise reduce its negative effects on tulip bulbs?

Review of tulips, *Fusarium* and ethylene

In the 1970 s, de Munk, Swart and Kamerbeek found that *Fusarium* isolates pathogenic on tulips produce at least 2,000 times more ethylene than nonpathogenic species or forms, and that ethylene production requires oxygen. The rate of ethylene production by infected tulips is also temperature dependent, and is maximal at 21C (falling off rapidly at lower, or higher temperatures). Using the cultivar White Sail , it was determined that a single bulb produced about 140 ul ethylene per day. More recent studies at Cornell University has established that tulip cultivars vary a great deal in how much ethylene is produced when they are infected by a common *Fusarium*. Some cultivars produced more than 6 times the ethylene as White Sail , and interestingly, many cultivars produced little to no ethylene when infected! This was discussed in detail in the May 2007 *Research Newsletter.*

To summarize, we know that:

- Healthy, non-infected tulip bulbs produce very little, if any, ethylene
- *Fusarium* makes ethylene, and does so in pure laboratory cultures
- *Fusarium* strains vary in the amount of ethylene they produce
- Tulip cultivars vary in the amount of ethylene *Fusarium* will produce when infected

Temperature has a profound effect on the rate and amount of ethylene produced, with a maximum at 21C.

Sources of ethylene in the tulip chain

With the major exception of the plant pathogen, *Fusarium*, as an ethylene source, the other ethylene sources in the tulip product chain are very similar to other perishable commodities. Internal combustion engines (e.g., forklifts, tractors, trucks), decaying plant matter, and storage in proximity to fruits, vegetables and flowers (which typically produce high levels of ethylene during their normal senescence phase) are all potential sources of ethylene in the tulip chain. Only in extreme cases, however, would any of these sources be likely to produce enough ethylene, for a long enough time, for injury to occur.

Ethylene concentration necessary for injury

The concentration of ethylene necessary to cause injury varies by many factors including:

- Cultivar
- Ventilation
- Time of year (early vs. late season)
- Length of exposure

Parameter being measured (e.g. early-season gummosis vs. late season flower abortion)

It is usually accepted that an ethylene level of 0.1 ppm should not be exceeded during tulip storage.

Reducing ethylene concentration in the surrounding air

Several methods are used to reduce ethylene levels in the air surrounding tulip bulbs. In order of their use in the industry they are:

- Ventilation
- Potassium permanganate
- Ozone or reactive-oxygen technology

These will be discussed below.

Ventilation.

The main technique used by industry to remove ethylene from the atmosphere surrounding bulbs is forced ventilation, the goal being to keep ethylene levels surrounding the bulbs at 0.1 ppm (ul/L) or less. Ethylene accumulation during transportation in temperature-controlled shipping containers is of special concern, and the maximal ventilation rate (>100 m^3/h) is less than optimal for complete removal of ethylene. The ventilation required is obviously affected by the degree of *Fusarium* infection in the cargo, and the rate of ethylene production by the fungus. The only drawback to ventilation as a technology is the electrical and capital costs for the installation and its operation.

Potassium permanganate.

In recent years, some export companies have been adding Ethylene Control sachets to their tulip shipments. These sachets (small tea bag-like packages, see Fig. 1) contain potassium permanganate, a chemical that is well known to absorb large quantities of ethylene. Potassium permanganate technology is used in many applications where ethylene scrubbing is required. While potassium permanganate is well known as an ethylene absorber, we conducted some experiments to demonstrate this. We sealed a 7 g Ethylene Control Sachet in a 2 liter jar, added ethylene to about 9 ppm, then followed the loss of ethylene as it was removed by the sachet. There was a small fan inside the jar, giving perfect air movement across the sachet. As you can see in Fig. 2, most of the ethylene was absorbed within about 30 minutes, and ethylene became nearly undetectable by 60 minutes. Ethylene Control sachets can absorb a great deal of ethylene. In experiments at U.C. Davis, it was found that a 7-gram sachet removed about 6.5 ml (6,500 ul) of ethylene before its capacity was reached.

While potassium permanganate is extremely effective in absorbing ethylene, it is less clear how effective this technology would be on a practical scale, that is, in a shipping container. In our studies, the volume of air relative to each sachet (we had 1 sachet per 2 liter jar) was much less than in a shipping container (which calculates to about 1 sachet per 60 liters), and the jar was sealed. In a container, there would be relatively less air contact per sachet, and at the very least, the rate of ethylene removal would be much slower than in Figure 2.

Another question is whether or not enough sachets are being used. If a shipping container (64 cubic meters, Maersk) holds 20 skids of 55 crates, and one sachet is used per crate, there are 1,100 sachets per container. Assuming the 7 gram Ethylene Control sachet, there is a total ethylene removal capacity of about 7,150 ml ethylene (6.5 ml/sachet x 1,100 sachets). If there is 1% *Fusarium* infection (that is, 5,500 infected bulbs in the container), and each bulb produces the classical (from de Munk s work in the 1970 s) level of 140 ul/bulb/day, then you have 770 ml ethylene/day from the infected bulbs (5,500 bulbs x 140 ul/bulb/day). If the container is in transit for 10 days, the total ethylene production is 7,700 ml, which is about 8% more than the capacity of the sachets to remove. And, this is only at 1% infection in some lots it may be more, and some cultivars are known to produce much more ethylene than 140 ul/bulb/day.

In all likelihood, Ethylene Control (or similar) sachets probably help reduce ethylene levels in commercial shipments, but we cannot give specific information as to the exact expected results until more commercial-scale experiments are done. It seems like there is no danger in their use (they should be disposed of properly by the receiver), but, like all technologies, they have limits and are *not* a substitute for shipping high quality bulbs with no infection.

Ozone or reactive-oxygen technology.

While it has long been known that ozone (O_3) can destroy (oxidize) ethylene, ozone-generating technologies have not been widely used in horticultural situations because the ozone concentration necessary to reduce ethylene can also cause direct injury to the crop. There have been, however, developments that may prove beneficial in the tulip industry. New technologies have been developed that produce ozone in combination with a variety of highly reactive oxygen species (such as superoxide anion, hydroxyl radical, singlet oxygen, etc. A company in Maryland, AirOcare, has developed equipment that is about the size of a desktop computer that could be installed into bulb storage rooms or into shipping containers. AirOcare has many of these units operating in fruit storage warehouses in South America, and claim excellent results with ethylene removal and killing of airborne spores and pathogens.

We have conducted initial tests on the unit at Cornell, and have concluded that it does indeed have the capability to oxidize (remove) ethylene from the atmosphere (see Figure 3). These are very preliminary trials, however. We plan more research to fully evaluate this technology for potential use in the industry. AirOcare was recently acquired by Ingersoll-Rand (owner of Thermo King, a major manufacturer of refrigeration equipment for shipping containers), and there seems to be interest in installing these units in commercial containers.

Reducing sensitivity of bulbs to ethylene

The other major technology that will hopefully soon impact the tulip industry is 1-MCP (otherwise known as EthylBloc, SmartFresh, or FreshStart). Research continues to be conducted on this material with tulips, and the indications are all favorable as to its effectiveness in *protecting bulbs from ethylene injury*. That is, after treatment with 1-MCP, tulips are immune from ethylene, at least for a period of 2-3+ weeks, depending on cultivar, ethylene level, time of year, etc.

Figure 1. A shipment of tulips received in North America with a sachet of Ethylene Control (potassium permanganate) included. This 7 gram sachet can absorb about 6,500 ul (6.5 ml) of pure ethylene.

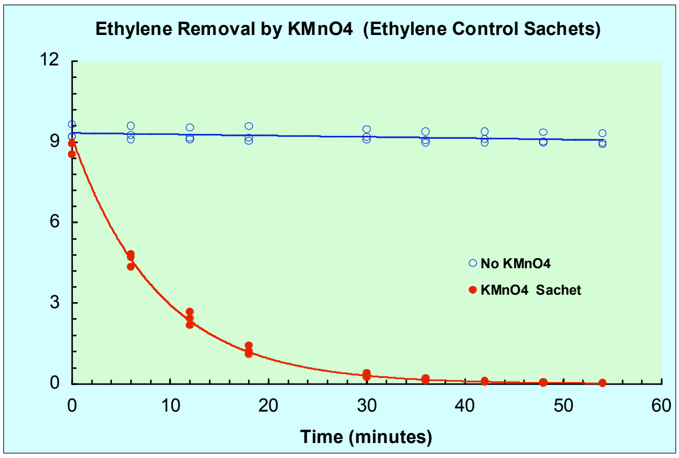

Figure 2. Removal of ethylene by potassium permanganate (7 gram Ethylene Control sachet). A sachet was sealed in a 2 liter jar with a small fan, and ethylene added to give an approximate concentration of 9 ppm. Samples were withdrawn and then injected into a gas chromatograph to determine ethylene concentration.

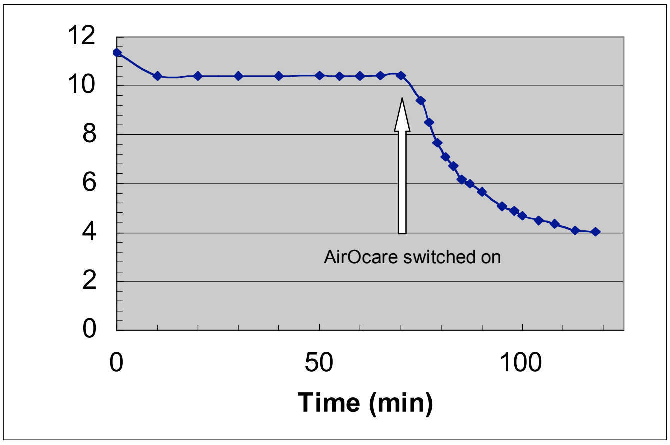

Figure 3. Destruction of ethylene by an AirOcare unit. The unit was sealed in a ca. 120 liter aquarium, and ethylene added to ca. 10 ppm. After a stable ethylene concentration was reached (70 minutes), the unit was turned on, and samples analyzed for ethylene by gas chromatography.

The effects of short-term ethylene exposures on the forcing quality of tulip bulbs

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PPO (Wageningen UR/Applied Plant Research)

In 2005 a sensitive and reliable ethylene analyzer (by Hatech) was introduced in the market in Holland. The device is used by growers and exporters to control the ventilation rate in tulip storage rooms by linking the ethylene signal to the climate computer. When the ethylene level is above the threshold level the valve opens, subsequently the ethylene level drops and the valve closes again etc.. Some growers or exporters use the analyzer to get an impression of the size of their *Fusarium* and ethylene problem. Batches of bulbs with higher (but unnoticed) *Fusarium* percentages, are detected immediately after they are placed in the storage room. In some cases the smell of a lot of bulbs appeared not to be a good indicator for the ethylene production by the bulbs. Users are content with the ethylene analyzer.

The advice up till now was to keep the ethylene level in the storage room below 100 ppb (0.1 ppm). However this threshold level was determined more than 25 years ago in experiments with a very ethylene-sensitive cultivar and long-term exposure periods. Since the introduction of the analyzer users are faced with ethylene levels above the thresholds levels: several hours at 1000 ppb or some days at 300 ppb. Although the cause of these high levels is often clear (*Fusarium* bulbs or heavy traffic around the farm in situations with little wind) it was not clear whether these short-term ethylene exposures of the bulbs have any negative effects on the bulbs.

Therefore PPO (Wageningen UR/Applied Plant Research) investigated the effects of the following ethylene treatments on 4 ethylene-sensitive cultivars:
Leen van der Mark, Christmas Dream, Yokohama and Hollandia:
1 hour 1200 ppb, 2 times a week, 2 weeks in a row
8 hours 1000 ppb, once a week, 3 weeks in a row
1 week 300 ppb

These ethylene treatments were applied:
during dry storage at 20 °C in July,
during dry storage at 20 °C in August
during dry storage at 20 °C in September
during dry cooling at 7 °C
during the rooting treatment in boxes after planting.
After all these treatments the bulbs were cooled and forced in a greenhouse in March.

After flowering it was concluded that **none of the above treatments had any negative effect on the forcing quality.** However, it must be taken into account that the bulbs were forced in the greenhouse in March. When forced earlier the ethylene treatments might have caused damage.

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