February 2006
Environmental Policy and Programs Branch

INFOSheet

Ministry of Agriculture, Food and Rural Affairs
www.omafra.gov.on.ca

Wind Machines for Protecting Grapes & Tender Fruit Crops from Cold Injury

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What are wind machines?

Wind machines are tall, fixed-in-place, self-propelled fans that pull warm air down from high above ground during a strong, effective, thermal inversion, raising air temperatures around cold-sensitive crops such as grapes and tender fruits (Fig. 1). They help protect crops from cold-injury that can affect the following year's crop and long-term plant health. There are four makes of wind machines currently used in Ontario, all with different specifications and features. See suppliers for specific design features. However, all wind machines are about 10.5 m high (34 ft) from the concrete pad they are anchored on, to the axis or centre point of their blades; all have long blades about 5.4 m to 6.0 m in length (18 to 20 ft); and all have blade speeds in the range of 400 to 600 rpm to generate huge volumes of moving air. Most wind machines have two blades, but currently there is one with four blades. Wind machines cost $30,000-$40,000 CDN to install and $20-40/h to fuel using propane, diesel, gas, or natural gas. Again, all design features depend upon manufacturer. However, regardless of make, all wind machines work under similar principles.

Why do wind machines make noise?

Wind machines need large engines operating at high rpms, plus long pitched blades in order to move large quantities of air a long distance. It is difficult to make wind machines quieter. Sound comes from the engine and the blades as they rotate. Slower blade speeds will reduce noise, but this can result in lower airflows, meaning more machines would be needed to cover the same area.

Some describe wind machine sound as being like a helicopter. Others say it is a whirring, thumping, or whining sound. Because it takes between 4.5 to 6.5 minutes for the head of the blades to make its full 360^{o} sweep around the tower (again, depends on manufacturer), the sound oscillates in intensity in a sinusoidal fashion (Fig. 2). Outside conditions during wind machine operation that affect sound movement and intensity and the:

- natural quiet of a rural, cold winter night
- lack of vegetation/woodlots to muffle sounds
- bounce effect of a thicker, denser, thermal inversion layer high above
- simultaneous operation of multiple machines
- low relative humidity of the cold air

Figure 1: Wind machine in a vineyard

Growers who own and operate wind machines only do so when they have to in order to protect their crops on land that is only zoned for agricultural use. It is not intentional that anyone, including wind machine operators, would be bothered by machine noise.

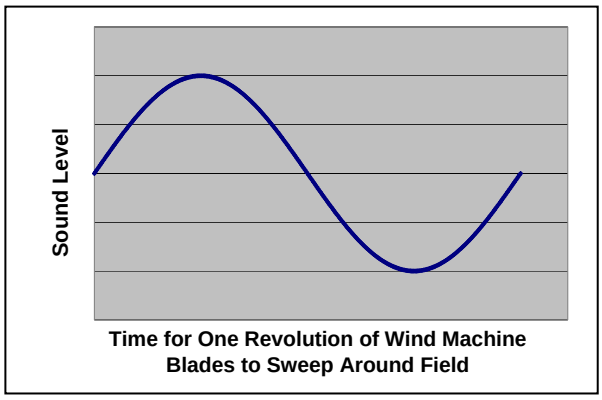

Figure 2: Wind machine sound varies over time in a sinusoidal manner as the blades sweep around the field.

What does a strong, effective, thermal inversion mean?

Under clear, calm night time weather conditions, heat is lost to the sky by long-wave radiation, resulting in rapid cooling and stratification of air temperatures near the plants at ground level (Shaw, 2001). Calm air means winds are less than about 6 km/h (4 mph) so there is minimal mixing of warm and cold air. Cold air is heavier than warm air, so it accumulates on the ground near the plants. If the air temperature is low enough, it may cause plant damage. Stratification of the air temperatures can be so great under winter conditions that at 20 m (66 ft) above the ground it can be as much as 5° to 10°C warmer (9° to 18°F) than at 0.625 m (2 ft) above ground. *Thermal inversions* are strong when this difference in air temperature is at least 3 to 4°C (5 to 7°F) warmer (Fig. 3). If ground air temperatures are expected to be at plant damaging levels for a period of time; if there is a strong thermal inversion; and if wind speeds are under 6 km/h, then this is considered a strong, effective, thermal inversion that might be used by a wind machine to help protect plants from cold injury. However, if there is no thermal inversion, there is no need to operate a wind machine as there would be no opportunity to warm the air at the ground.

Can machines generate electricity?

Wind machines are different than wind turbines. Wind turbines are designed to create electricity by taking advantage of high winds. Wind machines **should not be even be operated during windy conditions** over about 6 km/h (4 mph) because the long, thin blades are not designed to handle these wind forces. Also, as wind speed increases, the blades create more noise as they chop through the wind. Regardless, under windy conditions it is unlikely there would be a strong, effective, thermal inversion anyway.

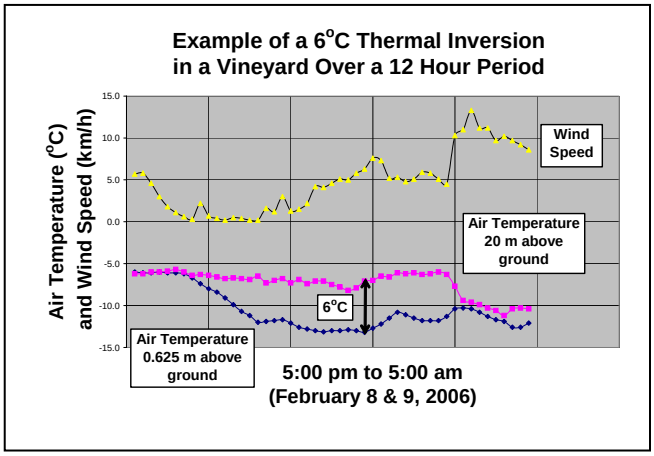

Figure 3: Air temperatures high above ground can be much warmer during thermal inversions, so if the air temperature around a crop may cause cold injury, it might be advantageous to use a wind machine to pull this warm down to raise the air temperature around the crop.

How do wind machines work?

The fan blades at the top of the tower are angled about 6° downward from the vertical direction so they pull air from above then blow it downward and outward at least 100m (325 ft). Different suppliers have different claims about how far their wind machines will blow air, and at what airflow rate (Fig. 4). At the same time as the blades are spinning, the entire head of the fan is rotating around the tower's vertical axis; so air is first circulated in one direction, say north, then east, then south, then west, then back where it started a few minutes earlier. This is accomplished by a gearing mechanism on top of the tower. So, air is circulated in all directions over time, covering a very large circle. If a wind machine completes this circuit too slowly, cold air could resettle, resulting in crop injury. Wind machines run independently, and are not synchronized in any way.

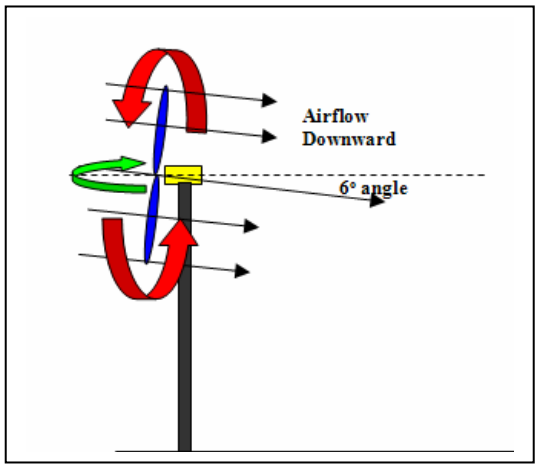

Figure 4: Wind machines pull air from high above the field, blowing it down and outward as the blades sweep around the field.

Why are growers using them?

Wind machines may be used to protect crops against cold injury at three main times of the year:

- Winter's very cold temperatures
- Spring's late frosts
- Autumn's early frosts

The major use in Ontario is against winter cold injury in grapes and tender fruit which is a serious problem that is getting worse (especially for more winter sensitive vinifera varieties). Normally, significant winter damage is observed 1 year in 10, however the last three winters (2003-2005) all resulted in observed vine and tree injury, with the last year (2004/2005) having some of the coldest winter temperatures on record. Grape yields in Niagara in 2005 were about 50% lower than average (Fig. 5). Some tender fruit growers also reported reduced crops. There have been greater temperature extremes and severe winter weather episodes. Recently, grape and tender fruit growers have experienced income losses, and installing wind machines has seemed logical, since their neighbours with wind machines have been harvesting more crop. Many growers say they cannot justify not installing wind machines and consider it a long-term best management practice.

Fortunately, conditions that can result in winter cold injury are not frequent, so even in a 'bad' year, wind machines are only used a few nights each year (and occasionally during the daytime).

Figure 5: Chambourcin (left) had no 2004/2005 winter cold injury, but Cabernet Sauvignon (right) did.

Where else are machines used?

Thousands of wind machines are used around the world in the US, Chile, Australia and New Zealand, but most are used to reduce the effects of late spring or early fall frosts. Ontario is one of the only places to use them to reduce the potential damage from very cold winter temperatures.

How do growers know when to operate their wind machines?

Most growers base decisions on when to operate wind machines by monitoring ground air temperatures at low areas of their farms compared to the air temperature at the top of a tower up to 20 m (66 ft) high (Fig. 6). Many growers monitor at one location per farm, but there should be several monitoring locations as conditions can vary from site to site due to elevation differences, trees, buildings, etc. Winter hardiness of perennial plants such as grapes and tender fruit, varies by variety, time of season, location, and many management factors, so temperatures that may cause damage will change throughout the winter season. So, where -15°C (5°F) might cause damage in early December, it might take temperatures as low as -22°C (-8°F) to cause damage in January.

Figure 6: Growers use a tall pole with sensors top/bottom for monitoring ground and inversion level air temperatures

Will there be wind machines in all vineyards & tender fruit orchards?

There are many areas of Ontario that might benefit from the use of wind machines and others that wouldn't. In most cases, wind machine installation has been limited to larger operations and properties. However, for some properties, installing a wind machine would be impractical. These scenarios might include properties with:

- Crop varieties are less temperature sensitive
- Odd-shapes, or small sizes
- Air 'drainage' that is already good
- Proximity to the relative warmth of Lakes Ontario or Erie, when the lakes are ice-free

Is anyone doing research work?

Industries using wind machines in Ontario are being proactive. In November 2005 an innovative 3-year applied research project began sponsored by the Grape Growers of Ontario (GGO) and the Wine Council of Ontario (WCO). The project runs until the end of 2008.

The researchers (Hugh Fraser, Ken Slingerland, Helen Fisher and Kevin Ker) are the authors of this **INFO**Sheet and are investigating the link of temperature data to crop response at a vineyard in Niagara-on-the-Lake (Fig. 7). They are also doing a region-wide crop hardiness monitoring survey for each of the next 3 years.

This project is partially funded by *CanAdvance*, through the Agricultural Adaptation Council of Agriculture and AgriFood Canada; by *CRESTech* through the Ontario Centres of Excellence; and by several private partners. The objective is to establish Best Environmental Management Practices for wind machine use, and find ways to use wind machines more effectively and less often, as wind machines are expensive to operate, and less use would minimize noise for neighbours. A Stakeholder Steering Committee of neighbours, growers, industry, suppliers, and government is in place to assist researchers throughout the project so that more informed decisions can be made.

There are several objectives to the project:

- To develop an advanced warning system to inform growers on best use of wind machines;
- To study and evaluate vine and tender fruit winter hardiness throughout dormant season;
- To study the behaviour of thermal inversions;
- To study wind machine noise and possible methods to reduce noise impacts off site

Figure 7: A 20 m (66 ft) tower monitors air temperatures from ground level to the top, plus wind speeds within the influence of a wind machine

References

Shaw, T.B., 2001. *Wind Machine Technology to Optimize Vineyard Conditions*. Brock U