

## NITROGEN DYNAMICS IN EUROPEAN VINEYARD SOILS, AND CONCLUSIONS FOR SOIL MANAGEMENT

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Nitrogen (N) is generally considered one of the most important nutrients and most likely limiting factors in agricultural soils. Besides irradiance, competition for N is thought to be the primary selective factor in plant development. Sustained soil fertility can only be guaranteed if the N removed with harvest products and other potential losses is replaced on a regular basis. To do this in the vineyard, we ought to know as much as possible about the dynamics of N in the soil, including annual input and output information, as well as the patterns of supply and demand during the season.

The vineyard is an open system. Nutrients are easily exchanged between the above-ground and the below-ground cycles. There is an ever changing and never ending flow within the system and between the system and its surround-

ings. Figure 1 summarizes the potential input to and output from a typical European vineyard. Both the annual import and export of N may be substantial. Between 10 and 250 pounds of organically fixed N per acre are mineralized and subsequently converted to nitrate each year from soil organic matter. Bacteria associated with legumes are capable of converting nitrogen gas dissolved in the soil water into plant-available ammonia. This biological N fixation may account for 10 to 200 lbs N/acre, depending on bacterium and legume species and abundance. Nitrogen fertilizer applications vary from zero to several 100 lbs/acre. At an annual precipitation of 30 to 50 inches, a range that covers most of Switzerland's vineyard locations, the N input from rainfall and snow alone (10 to 50 lbs/acre) may be several fold the export with harvest products.

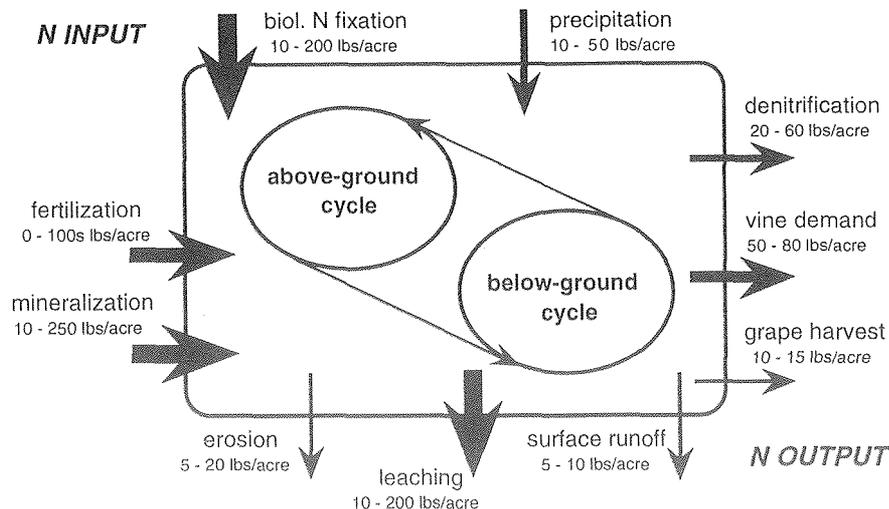


Fig. 1. Annual nitrogen input and output in a vineyard as an open system.

Grapevines need between 50 and 80 pounds of N per acre to satisfy their annual requirements for vegetative growth and fruit production. Leaves and pruning wood, however, may remain in the vineyard. In Europe the bunch stems and the pomace are often returned there, too. Therefore, apart from N losses, only the N exported in must or wine needs to be replaced in many European situations. At an average yield of 3.5 to 4 tons of grapes per acre, this is no more than 10 to 15 lbs N/acre. This is insignificant compared to other agricultural systems. What is important are the potential losses of N to the environment. Between 10 and 200 pounds of N per acre may be leached out as nitrate each year, especially during heavy rainfalls. Another 20 to 60 lbs/acre may be lost to denitrification, mainly during warm periods. Denitrification is the microbial conversion of soil nitrate to gaseous nitrogen, due to high organic matter and elevated water content in the soil. Erosion (5 to 20 lbs/acre) and surface runoff (5 to 10 lbs/acre), in particular on steep slopes, as well as ammonia volatilization, can also contribute significantly to the total N output.

The introduction of various cultural practices across Europe, such as the use of cover crops and terraces has recently contributed to decreasing nutrient losses. Still, many vineyard soils carry the burden from excessive N fertilization in the past decades. This has resulted in elevated ground water nitrate content in most of Europe's viticultural areas. A surplus of soil-N may also increase leaching of other nutrients, in particular calcium and magnesium. This has led to further problems with magnesium deficiency in European vineyards. In addition, fungal diseases and physiological disorders are favored by high N levels in vines arising from luxury consumption. It is important to adjust the level of N fertilization to avoid these problems.

We need to know the N uptake pattern of grapevines throughout the season. The bulk of the annual demand for N occurs from bud break to the end of bloom. During this period the vine is heavily dependent on the N reserves stored in its permanent structure. Root growth, nutrient uptake and, in particular, N assimilation are only possible when sufficient assimilates are supplied from the shoots. The roots start growing later than the shoots, generally around the 6- to 8-leaf stage. This moment marks the beginning of the most rapid growth period of the vine, lasting until fruit set is complete. This is also the period of greatest demand for N, which is mostly taken up as nitrate. The mineralization rate in the soil is too low at this time to meet this peak demand, even though considerable differences exist between wet and dry soils (Fig. 2). Thus, the N reserves in wood and roots reach a minimum around bloom time.

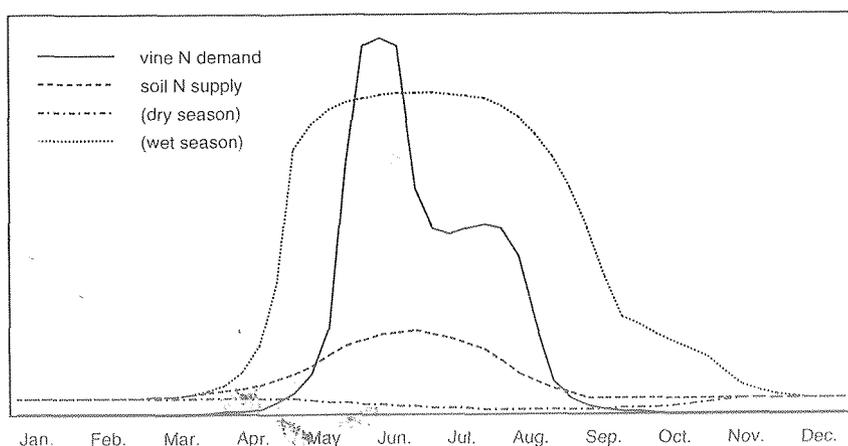


Fig. 2. Patterns of nitrogen supply and demand in a vineyard throughout the season.

The aim of timing N supply should be to optimize N availability during this critical period. Traditional recommendations in European viticulture have been to apply N fertilizers at bud break or even during dormancy, preferably between February and April. This practice unfortunately increases the potential for N losses before significant uptake can occur. This N is no longer available to the vines. Fertilizing too early in the season is not only a waste of time and money, it can also lead to considerable ground water pollution. This cannot be tolerated in integrated and sustainable grape production. Revised fertilization guidelines tend to delay N applications until bloom or later to minimize losses. Such loss can not be avoided, especially when heavy rainfalls follow shortly after fertilization. Peaks in soil-N content around bloom time accelerate shoot growth, inhibit root growth and hinder the replenishment of reserves used for early growth. This may lead to unfavorable canopy structures, delay fruit ripening and increase the vine's susceptibility to water stress during the summer months.

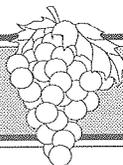
The so-called "adaptive nitrogen management" was recently introduced by the Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture in Wädenswil, Switzerland. The principle of this approach is to regulate the soil's potential for N storage and mobilization by using natural, green floor covers and soil cultivation techniques instead of applying N fertilizers. This leads to a slower rate of nitrate accumulation because N must be mineralized first. On the other hand, soil nitrate remains at a higher level for a longer period of time. In this context it is also interesting to know that an acre of "clean", open soil can store nearly 100 pounds of N (the equivalent of 350 pounds of ammonium nitrate). On the other hand, a soil with green cover is capable of storing up to 550 pounds of N per acre (2000 pounds of ammonia nitrate). The storage capacity for nutrients is greatly improved by the

continuous plant cover. Simultaneously, the soil's water-holding capacity is also increased, due to the higher organic matter content in the soil.

The goal of adaptive N management is to synchronize supply and demand. During periods of low demand by the vines, N from rainfalls and mineralization is absorbed and immobilized in organic form in the soil's biomass. Since mineralization starts at temperatures above 35-40°F, weeds should be allowed to grow throughout the winter and spring to conserve N in the topsoil. Just prior to the period of increased demand, that is before bloom, the competition arising from growing weeds is eliminated by mowing them. If the vines' N demand is very high or available N is low, the soil is superficially cultivated to enhance mineralization rates. After flowering, the vines' N demand can usually be met from natural N supply by mowing alternate rows. During dry periods the competing weeds must be mown frequently; and in the case of prolonged dryness, the soil should be cultivated lightly in alternate rows. Supply usually exceeds demand after veraison (Fig. 2). Again, this N should be immobilized by permitting the weeds to grow as long as possible to prevent N losses during the winter.

This procedure minimizes nitrate leaching, because N is almost permanently in organic form. Mineralized N is taken up immediately by vines or weeds. This simultaneously decreases ground water pollution and erosion. There are benefits beyond this. Nitrogen is available when the vine needs it most and supply is

optimal. The allocation of photosynthesis products to the various plant parts is not disturbed by excessive N assimilation. This leads to a balanced ratio between vegetative and reproductive growth, increasing bud fertility and fruit set. Nevertheless, fruit quality may be superior, because of lower susceptibility to fungal diseases and an improved light environment in the cluster zone. The ecosystem is stabilized due to the high biological diversity. Also the number of beneficial arthropods increases due to the high variety of forage plants, regulating potential pest species at low population densities. In the long term, healthier and riper grapes, negligible erosion and N losses, and a stable ecosystem will also yield financial benefits. Last but not least, soil management may be cheaper than fertilizers and herbicides: "green" is better than "clean." ❖



## FROM THE EDITOR

*Martin Goffinet*

As the season for bud break is imminent, it is important that growers consider the annual cycle of vine activity and the availability and use of nutrients in their vineyards. Maintenance of optimal vine size and yields depends on the sources, availability and use of nutrients by the vine. Each of these nutrients, whether a major or minor element, has its own annual pattern in the above regard. Since the most applied nutrient in vineyards is nitrogen, it is essential that growers understand how this nutrient moves through the vineyard system of soil-plant-atmosphere.

Dr. Markus Keller presents a report of nitrogen cycling from the European perspective. Dr. Keller has just completed work as a Swiss National Science Foundation Postdoctoral Fellow in the Department of Food Science and Technology at Cornell University's Agricultural Experiment Station in Geneva, NY. The information presented comes from Keller's doctoral research in grapevine stress physiology, working at the Swiss Federal Research Institute in Wädenswil. Although the work was not done in New York, the mechanisms of nitrogen movement are readily transferred to our situations.

Yes, vine disease season will soon be here, too. Powdery mildew is likely the grapevine disease most growers worry about in New York State, and the East in

general. Powdery mildew control has many variables associated with it, not the least of which is mildew's ability to gradually lose susceptibility to fungicides that are supposed to inhibit sterol biochemistry in the fungus. Such resistance can be worsened or alleviated by the choices growers make in their disease management program. In this issue, Wayne Wilcox, a Cornell Associate Professor in grapevine pathology, provides readers information on powdery mildew control in the face of fungicide resistance.

Because the next issue will come out in mid summer, I'll take the opportunity now to say, "Have a great season!" ❖

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# UNDERSTANDING AND MANAGING POWDERY MILDEW RESISTANCE TO STEROL-INHIBITING (SI) FUNGICIDES

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In New York, sterol-inhibitor (SI) fungicides have been used for control of grape powdery mildew (PM) since the introduction of Bayleton in the early 1980s. By the end of that decade, Rubigan and Nova also became available. These fungicides have set the current standard for powdery mildew control, but their performance, particularly that of Bayleton, has appeared to decline in a number of vineyards over the last few years. Although fungicide resistance has been widely suspected as the cause of the problem, there was no way to prove or disprove this supposition until recently. In the following article, we describe the general phenomenon of resistance to the SI fungicides, how it develops to damaging levels, and the best ways of minimizing or avoiding it.

**SI resistance development.** The development of resistance to SI fungicides is fundamentally different from the development of resistance to fungicides such as Benlate or Ridomil. The latter group is characterized by an "all or nothing" type of resistance. In the latter group, a very small subpopulation of the fungal pathogen is completely immune to the fungicide (regardless of rate) before it is ever sprayed, whereas the vast majority of individuals are fully susceptible. Thus, with each spray, the susceptible majority is controlled whereas the immune subpopulation survives, multiplies, and quickly dominates within the vineyard. At this point, control failures occur suddenly, and the immune pathogen isolates (individuals) are easily detected and defined.

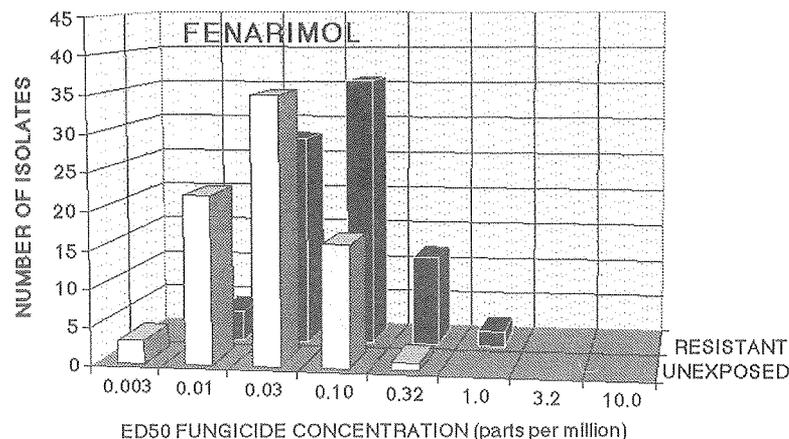
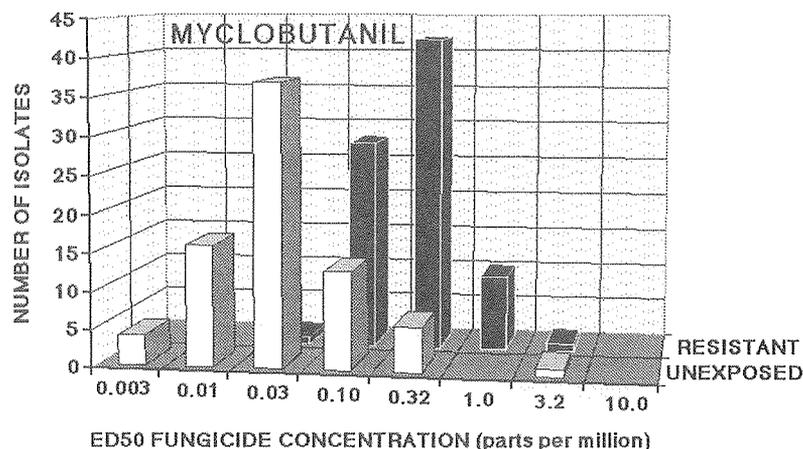
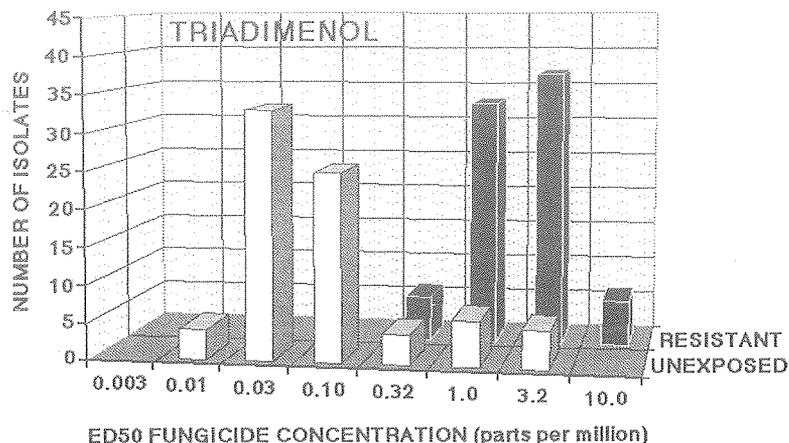
In contrast, resistance to the SI fungicides is of the "shades of gray" type, wherein there is no distinct immune subpopulation. Instead, fungicide sensitivity is distributed along a so-called "normal" (or bell-shaped) curve, with most individuals having "average" levels of sensitivity, a few being somewhat more and somewhat less sensitive than average, and fewer still being much more or much less sensitive than average. Thus, at lower fungicide exposure rates (caused by low rates in the tank, poor spray coverage, extensive spray intervals, etc.), a few of the least sensitive members of the population slip "through the cracks" and are able to grow and reproduce more actively than the more sensitive members. It is important to notice that these individuals are not immune to the fungicide; it's just that below certain rates, they are only partially inhibited. As the least sensitive members of the population continue to survive certain sprays over a period of time, they gradually build up and disease control begins to diminish.

Because there is no distinct immune subpopulation of the pathogen, it is difficult to define "sensitivity" and "resistance" to the SIs. For instance, an individual PM isolate may be "sensitive" to a 6 oz rate but "resistant" to a 3 oz rate of Fungicide A. However, it still may be sensitive to 3 oz rate of Fungicide B, and resistant to a 1 oz rate of that material. The critical question is: how do

you identify such isolates with respect to their reactions to field rates of the fungicide(s), and how many of them have to build up in the vineyard before you get into trouble?

**Real-world examples.** To answer these questions, we collected and tested a total of 160 isolates of PM fungi. There were 80 isolates from two vineyards that had never been sprayed with SI fungicides and also 80 isolates from two vineyards with a long history of SI use and in which Bayleton no longer provides good control of PM. Interestingly, Nova and Rubigan still provide good control in these vineyards, both of which are located in the Finger Lakes region.

For the tests, solutions of fenarimol (Rubigan), myclobutanil (Nova), and triadimenol (the active form of Bayleton) were prepared in a series of eight concentrations, with the strongest concentration more than 3,000 times greater than the weakest. 'Chardonnay' leaf disks were soaked in the different fungicide solutions and inoculated with single isolates of the PM fungus. Growth on each disc was then measured after an incubation period. From these measurements, it was possible to determine the fungicide concentration that provided a 50% reduction of growth (ED50) for each isolate. In general, ED50 values are considered to be the most reliable measure of sensitivity to SI fungicides.



The resulting **population** profiles presented in Figure 1 explain a lot about PM resistance to the SIs. Note that for triadimenol (the active form of Bayleton), the most common ED50 values among the unexposed population (i.e., about 50% of the isolates) ranged from 0.03 to 0.10 parts per million (ppm). A few isolates had ED50 values that were 3 to 10 times lower than this (i.e., they were that much more more sensitive to the fungicide), whereas a few had ED50 values that were about 10 to 30 times higher (i.e., they were 10 to 30 times less sensitive = more resistant).

Now, compare this distribution with that from the resistant vineyards. Note that whereas the least sensitive isolates detectable in the unexposed vineyards (the 1.0 plus 3.2 ppm categories) made up only about 10% of the total population, these two categories accounted for nearly 80% of the population in the resistant vineyards. Furthermore, isolates that were 10 to 30 times more resistant than these (10.0 ppm) made up an additional 8% of the population, although they were so rare in the unexposed vineyards that we couldn't detect them there. In a nutshell, prolonged SI usage in the resistant vineyards had pretty much wiped out most sensitive PM isolates but allowed the less sensitive isolates to survive and multiply, causing the population makeup to "shift." As the graph shows, average levels of sensitivity are about 30 times lower (i.e., average resistance levels are 30 times higher) in these problem vineyards compared with the unexposed vineyards. Once this shift occurred, Bayleton stopped providing acceptable levels of control.

However, recall that Nova and Rubigan are still working in these "resistant" vineyards. A look at the graphs in Figure 1 shows that Nova (myclobutanil) sensitivity has shifted

Figure 1. Composite distributions of sensitivities to three SI fungicides in "unexposed" vineyards never sprayed with SIs (unexposed) vs. "resistant" vineyards in which Bayleton (triadimenol) provides poor control but Nova (myclobutanil) and Rubigan (fenarimol) are still effective. Isolates to the left of the scale are most sensitive to the fungicides; isolates to the right are most resistant.

approximately 10-fold in the resistant vs. susceptible vineyards (0.32 vs. 0.03 ppm for the most common isolates, respectively), whereas Rubigan (fenarimol) sensitivity has shifted about 3-fold (0.10 vs. 0.03 ppm, respectively). This suggests that "cross-resistance" to Nova and Rubigan has started to develop, but that it is proceeding at a slower pace than for Bayleton. Apparently, sensitivity shifts in the 3- to 10-fold range are still allowing good disease control, whereas a 30-fold shift is not. How long it will take for Nova and Rubigan shifts to continue to the point that these materials no longer provide acceptable PM control is heavily dependent on how they are used in the future.

**SI resistance management.** Understanding the above concepts suggests several components of a general, integrated anti-resistance strategy. The critical point to remember is that **it's all a numbers game**. That is, we're trying to minimize the number of "problem" PM isolates that survive the sprays, multiply, and keep on causing disease. With this in mind, the three basic components are:

1. Reduce the absolute **SIZE** of the powdery mildew population.
  - Limit the amount of primary inoculum at the start of the season by getting good disease control the previous year.
  - Control pathogen multiplication during the season by providing good fungicide timing (don't wait too long to start your program), intervals (don't stretch SI sprays beyond 14 days), coverage, and rates (don't cheat).
2. Reduce the **PERCENTAGE** of resistant (thus, selectable) isolates in the population.
  - This is determined entirely by the fungicide rate that you put on the vine, not in the tank. So, don't cheat on the rate and get good coverage.

3. Reduce the **OPPORTUNITIES** to select resistant isolates.

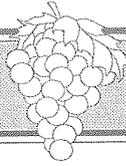
- Limit the number of SI sprays (suggest 3 to 5 maximum).
- Don't keep spraying SIs throughout the summer once PM really gets cooking. If the least sensitive 1 or 2 or 10% of the isolates are going to survive a spray and multiply, let it be a few thousand rather than a few hundred million individuals.

For those of you who are a bit contrary and want to burn these materials out, we offer the following **recipe for powdery mildew resistance**, based on these same principles:

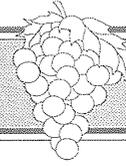
1. Let PM get away from you most years.
2. Don't start sprays until disease gets well established.
3. Cheat on rates, intervals, and spray coverage.
4. Spray, spray, spray once the epidemic gets going.

Experience shows that this will do the job quite well. 🍷





## ANNOUNCEMENTS



**James Kamas Leaves Lake Erie Grape Program.** As of February 23, 1996, the Lake Erie Regional Grape Program lost its regional Cooperative Extension specialist in grapes, Mr. James Kamas. Jim has accepted a position as Extension Horticulturist/Fruit Specialist with Texas A&M University. He will be stationed at Fredericksburg, Texas, about 70 miles west of Austin, where his primary responsibilities will be to work with commercial peach and grape producers in the Texas Hill Country. He will, however, have some statewide peach responsibilities and otherwise have freedom to work with local producers of other commodities, for example, apples, pecans and some commercial vegetable work. The Hill Country has long been a traditional peach area and has seen rapid expansion in wine grape planting and winery construction. Jim will be located in what many feel is the most beautiful part of Texas. There is a great deal of seasonal tourism and direct marketing to those people results in additional revenue for commercial growers. Unlike the eastern part of Texas, the Hill Country is relatively arid and rocky, with most of the commercial horticulture production in wide river valleys with deep, well drained soils. Virtually all commodities there are produced with irrigation.

Jim had mixed emotions about leaving New York's people, places and grape industry. "I have enjoyed and profited from my relationships with growers and university faculty and staff. In parting, I want to thank all of you for your friendship and for what you have taught me about viticulture. I consider myself a richer person for the past eight years." A "Recognition Dinner" was held for Jim on February 10 in Dunkirk, NY, where many of his industry contacts, colleagues at the Fredonia Viticulture Lab and Cornell grape research/extension staff gave him a proper send-off to Texas. We all wish him success in his new assignment.

### Upcoming Events

**17-20 July 1996, Fourth International Symposium on Cool-Climature Viticulture & Enology: "Applying Current Viticulture and Winemaking Technologies to Maximize Wine Quality."** Riverside Convention Center, Rochester, New York U.S.A. **This symposium is in conjunction with the 21st Annual Meeting of the Eastern Section of the American Society for Enology & Viticulture.**

The Cool-Climature symposium will present the world's best current technical and scientific data on issues in grape and wine production in cool climates, emphasizing practical applications. Hosted by the American Society for Enology & Viticulture/Eastern Section. Sponsored by the International Society for Horticultural Science, and the American Society for Enology and Viticulture. The program will include keynote speakers, oral and poster presentations, workshops, and a trade exhibition.

### Symposium Program Areas:

Adaptation to Regional Environments; Vine Stress Physiology; Ecologically Sound Grape and Wine Production Methods; Wine Sensory Attributes—Techniques of Measurement; Flavor Production in the Vineyard; Flavor Production during Fermentation; Understanding the Genetic Basis for Grape and Wine Production; and Economics and Marketing.

**Workshops:** Wine Aroma Defects; Wine Evaluation; Winery Sanitation; Sparkling Wine Production; Yeast and Bacterial Starter Cultures; BATF Compliance; Assessing Cold Injury in Grapevines.

**Seminars:** Information Management; Vineyard Mechanization; Integrated Pest Management; Flavor Adjustment in the Vineyard; Wine Marketing.

### Trade Show and Exhibitor

**Seminars:** Two full days of trade exhibits (July 18 and 19) and exhibitor presentations.

In addition, there will be day passes that will allow one-day entrance for those who have specific parts of the program or trade show in mind. Tours to area attractions are also available, as are a welcome dinner and an awards banquet.

To receive particulars of the meeting, accommodations, etc., contact: American Society for Enology and Viticulture/Eastern Section, Department of Food Science and Technology, New York State Agricultural Experiment Station, Geneva, New York 14456-0462 USA. Fax: USA-315-787-2397.

Gratitude is expressed to those organizations whose support makes possible ongoing and valuable research activities for the benefit of the State's grape industry. Major funding is provided by the  
**New York State Wine & Grape Foundation; the Grape Production Research Fund, Inc.;**  
**and the J.M. Kaplan Vineyard Research Program.**

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**Got A Question?** We are trying to address the many questions from grape growers and processors that come to Cornell's grape research community. We invite you to write to us at *Grape Research News* to bring to our attention any questions you have about grapes. We will see to it that those questions are answered by someone knowledgeable in the area of your concern.  
**Save yourself a long distance phone call. Put it in writing on the back of form below, cut it out, and send it to us.**

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