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Affected Syrah in the foreground: third leaf Syrah "Shenandoah" clone on 5C rootstock, with strong symptoms. Adjacent block (background) not affected.



SYRAH IN CALIFORNIA

Decline or Disorder?

BY Mark Battany, Adib Rowhani, & Deborah Golino

Growers of Syrah in California vineyards have observed a variety of symptoms in recent years that suggest this popular variety may be subject to unique problems. Reports include cases of leaf reddening, scorching, swollen graft unions, and stem necrosis symptoms. These symptoms are often associated with genetic incompatibility and/or virus infection.⁵

Some viticulturalists have expressed concern that affected vineyards might be showing symptoms of the disease known

in France as "Syrah Decline." At this time, the cause of that disease is unknown.

The authors of this report conducted an extensive survey of California Syrah vineyards in 2002 and 2003. The survey

did not confirm the presence of Syrah Decline in California. Rather, most affected vineyards were found to have problems that resulted from environmental stress or poor cultural practices.

In addition, on the Central Coast, significant acreage is affected by a problem we are calling "Syrah Disorder." We believe Syrah Disorder is a separate problem from Syrah Decline and propose some possible causes later in this report.

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Affected vine on left, unaffected vine on right. When vines are affected, generally the entire canopy shows symptoms rather than individual leaves and shoots.

The French situation

Syrah Decline is a well-documented problem in France.^{1,6,7} It is characterized by swelling and cracking of the graft union and early leaf reddening (as early as July; see Figures I and II). French scientists at ENTAV have been studying this problem since 1999 with efforts to determine whether there is any correlation between Syrah Decline and other conditions, such as poor graft unions, crown gall infection, genetic incompatibility, traditional viruses, new viruses, fungi, viroids, and environmental interactions.

At this time, our French colleagues have concluded that the problem has no simple explanation. Consequently, they are investigating solutions involving a number of possible causes, including new, unknown viruses.

California statewide survey

In 2002, we began our statewide survey of Syrah sites to determine whether the disease Syrah Decline, as reported from France, occurs in California. Our goals were to visit Syrah sites in which problems have



Swelling and cracking at the graft union characterize the Syrah Decline disease in France.

been observed, including graft union abnormalities and reddening of leaves; to test selected samples for pathogens by using molecular and biological assays; and to establish a small field trial with Syrah grafted onto select rootstocks to attempt to induce observed symptoms.

Growers, UC faculty, and Cooperative Extension staff were asked to help us identify possible sites based on symptoms. Seventy-seven Syrah vineyards in 10 California counties were surveyed and inspected in 2002 and 2003. Counties included Calaveras, El Dorado, Madera, Merced, Napa, Sacramento, San Joaquin, San Luis Obispo, Sonoma, and Stanislaus.

Twelve clones, seven field selections, and 12 different rootstock varieties were represented (Table I), and more than 50 different combinations of clone and rootstock were observed (Table II). Geography ranged from central San Joaquin Valley to Sierra foothills to coastal valleys, with temperatures as high as 110°F and as low as 19°F.

All vineyards were drip irrigated, and many vineyard managers reported practicing deficit irrigation to control vigor. Many were planted as green-growing benchgrafts, some as dormant benchgrafts, and others as field-budded vines.

Observed symptoms included mild and severe vertical cracking on the

Table I: Survey of Virus Test Results in California Syrah Vineyards

Clone/ Selection	# Vineyards Surveyed	Rootstocks	Virus test results
1 Syrah FPS 01	4	110R, 99R, Freedom, Teleki 5C,	No virus detected.
2 Syrah FPS 07	4	101-14, 420A, Schwarzmann, SO4	No virus detected except RSP in 2 vineyards.
3 Syrah ENTAV-INRA 99	2	3309C, 99R	No virus except RSP in 2 vineyards.
4 Syrah ENTAV-INRA 100	3	3309C, Freedom, Teleki 5C	No virus except RSP in 2 vineyards.
5 Syrah ENTAV-INRA 174	6	110R, Freedom, SO4, Teleki 5C	GLRV2 detected in 1 vineyard. RSP detected in 5 vineyards.
6 Syrah ENTAV-INRA 383	1	110R	No virus detected.
7 Syrah ENTAV-INRA 877	4	101-14, 3309C, Freedom, Teleki 5C	No virus detected except RSP in 4 vineyards.
8 Syrah Estrella	15	101-14, 110R, 1103P, 140Ru, 44-53M, Freedom, Kober 5BB, Teleki 5C, own roots	No virus detected except RSP in 1 vineyard.
9 Syrah Noir	8	101-14, 110R, Freedom, Kober 5BB, Teleki 5C	GLRV2 detected in 2 vineyards; GLRV9 detected in 2 vineyards; GVA detected in 1 vineyard; GV detected in 1 vineyard; RSP detected in 8 vineyards.
10 Syrah Beaucastle	2	110R, 44-53M	No virus detected except RSP in 2 vineyards.
11 field selections/ unknown	18	039-16, 99R, 110R, 101-14, 3309C, Freedom, Schwarzmann, SO4, Teleki 5C,	GLRV2 detected in 2 vineyards; GVA detected in 1 vineyard; GV detected in 1 vineyard; RPS detected in 5 vineyards.
12 Shiraz FPS 01	3	99R, 3309C, SO4	No virus detected except RSP in 1 vineyard.
13 Shiraz	8	101-14, 1103P, 140Ru, 420A, Schwarzmann	No virus detected except RSP in 2 vineyards.
Total More than 12 clones/selections	78	13 different rootstocks	GLRV 2, GLRV 9, GV, GVA detected in less than 4% vineyards; RSP detected in approximately 50% vineyards.

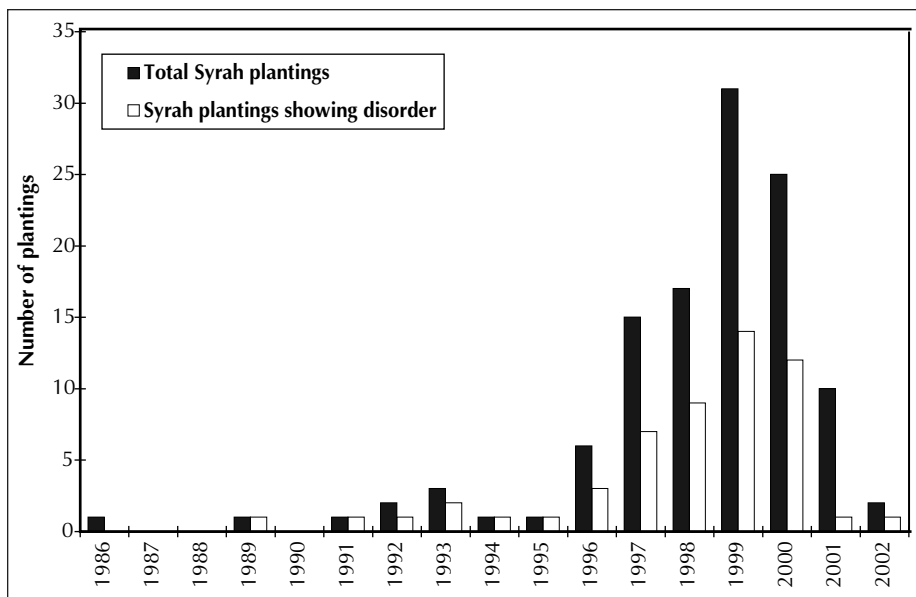


Figure 1. Incidence of Syrah Disorder on the Central Coast in 2003, by year of planting.

trunk, interveinal burgundy red leaves (typical of leafroll-virus symptoms), leaf-margin reddening and necrosis, and swelling at the graft union.

No strong pattern emerged between specific management practices, site, clone, rootstock, or type of planting material, and observations of symptoms or reports of problems. Individual healthy vineyards were observed planted with all the common Syrah clones, making it unlikely that a disease carried with propagative materials was involved.

In many cases, symptoms in problem vineyards could be attributed to specific factors, including frost damage of young vines, water stress (including lack of water to young vines and poor drainage), poor planting and training techniques (Figure III, IV), and other factors causing root stress, including known presence of *Armillaria* root rot.

Only in the Central Coast were problem vineyards observed for which no obvious environmental or management problem existed. These vineyards will be discussed in more detail below.

Infection with known viruses (based on test results) did not seem to be a common factor in problem grapevines identified by vineyard managers.

More than 1,500 PCR tests were completed on 132 samples. All samples were tested for viruses that are associated with

graft union disorders: leafroll type 2, grapevine virus A (GVA), grapevine virus B (GVB), grapevine virus D (GVD), Rootstock Stem Lesion-associated Virus (GRSLaV), and Rupestris Stem Pitting-associated Virus (GRSPaV). Selected samples were tested for additional viruses. A summary of results is presented in Table I.

Statewide, results were very similar. Approximately 95% of the samples tested negative for viruses typically associated with graft-union disorders. Several samples tested positive for leafroll type 2, leafroll type 9, and for vitivirus.

The general vitivirus primer used for these tests is experimental, detecting the vitiviruses GVA, GVB, and GVD. One would normally expect that a sample testing positive for the vitivirus primer would also test positive for GVA, GVB, or GVD.

However, this was not the case in this study. We are continuing to work on this inconsistency, to explore if there is a different, as yet unidentified, vitivirus in these samples. Although these viruses are sometimes associated with graft-union disorders, we did not get consistent positive results among samples from the same vineyard, neither were they correlated with symptoms.

Approximately 50% tested positive for Rupestris Stem Pitting-associated Virus (RSP). RSP, believed to be a mild virus, is known to be widespread in

California. It is not known to cause the symptoms associated with Syrah Decline.

Many sites tested negative for all viruses, yet showed reddening. However, these vines also suffered from large cracks and splits in the bark, which appeared to be due to frost damage. Such damage can also cause leaf reddening. In other cases, plants with no obvious red leaf symptoms tested positive for GLRaV-2, apparently harboring a latent infection.

In general, far less virus was found in Syrah than is usually found in some major grape varieties grown in California. In previous survey work, Chardonnay, Zinfandel, and Cabernet Sauvignon have been tested from diverse vineyard locations and are much more likely to be infected with both leafroll viruses and vitivirus.

We believe that Syrah in California is relatively free of virus problems because it has become popular relatively recently, so nearly all the clonal material in the trade has come from clean stock programs and been tested by formal importation programs.

Syrah Disorder on the Central Coast

Although most problem Syrah vineyards we visited could be explained by



Leaf reddening can occur as early as July when a vine is affected by the French Syrah Decline.

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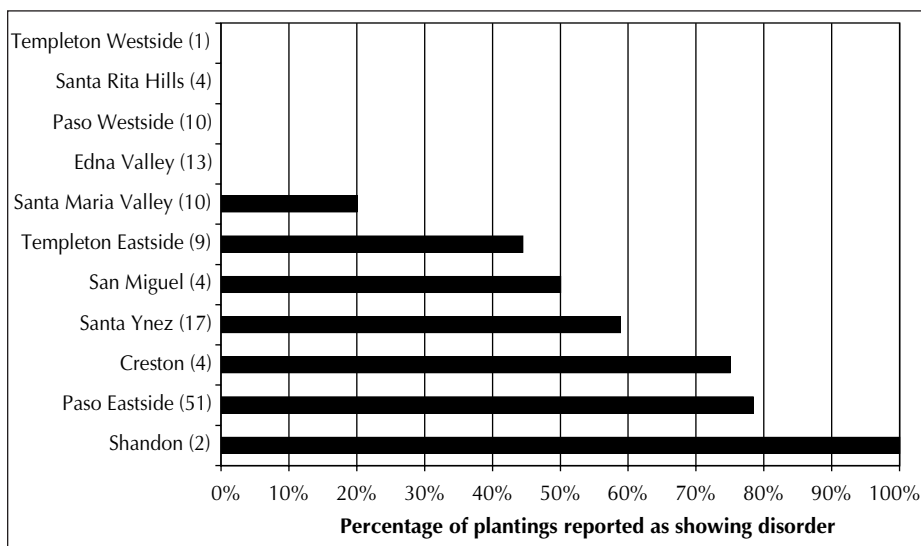


Figure II. Incidence of Syrah Disorder on the Central Coast in 2003, by location. The numbers in parenthesis refer to the sample size for each category.

cultural or environmental factors, Syrah grown in the warm climate areas of the Central Coast has suffered an increasing incidence of a generally uniform disorder during the past three seasons. This disorder, which we call Syrah Disorder, appears to be relatively unknown in other parts of California, but has affected significant acreage in this area.

Typical symptoms of Syrah Disorder include:

- Leaf reddening and senescence beginning around veraison or soon thereafter, with visual leaf symptoms that somewhat resemble a blend of leafroll virus, severe potassium or magnesium deficiency, salt burn, and/or severe water stress;
- Limited ripening of the fruit beyond veraison; the resulting juice has very low soluble solids, high pH, high potassium, and very poor color;
- Undesirable, difficult-to-market fruit, and reduced wine quality.
- Adjacent blocks of other varieties under the same management and environmental conditions do not display any similar characteristics to those above.

There are approximately 4,400 acres of Syrah grown in San Luis Obispo and Santa Barbara counties. We surveyed the area's Syrah growers after the 2003 harvest regarding Syrah Disorder. Forty-five growers responded, representing 125 individual plantings of Syrah, Shiraz, and Syrah Noir.

This brief, non-scientific survey requested the planting year, rootstock, clone, location, certification status, and whether or not symptoms were observed in 2003 for each individual planting. Based on the survey results, there were no correlations between occurrence of the disorder and specific clones, rootstocks, or year of planting (Fig. I).

There was, however, an obvious correlation with location: The hotter, drier areas in the Central Coast showed more occurrences of the disorder, while the cooler, wetter areas showed few or no occurrences. For example, in the warmest inland areas east of Paso Robles, 78% of the plantings showed the disorder, and likewise in the warm inland area of Santa Ynez Valley, the percentage was 58% (Fig. II).

Non-certified material was more likely to be affected (Fig. III). Several growers who have had successive poor years with Syrah have resorted to removing the plantings.

Some of the possible causes of the disorder that have been receiving attention among growers include:

- An as-yet unknown virus or other pathogen;
- Graft-union disorders;
- Nutritional imbalances, particularly potassium, magnesium and phosphorus;
- Physical root impairment, such as J-rooting;

- Increased vine water stress due to recent drought, salinity, and changing irrigation practices;

Based on our 2002 statewide virus survey, we believe that some of the factors above can be eliminated as possible causes of the disorder. Our testing did not indicate that a known virus was responsible for the symptoms that growers are reporting. The majority of growers in the area reported that there were no graft union problems in their affected vineyards.

There does not appear to be any obvious correlation between the disorder and soil or vine nutrient status. Distribution of the disorder across a wide variety of soils tends to decrease the likelihood that a specific nutrient imbalance is the primary cause, particularly when other varieties perform perfectly well under the same conditions, and the same Syrah plantings may have performed well in previous years. Physical root impairments due to improper planting methods could contribute to the symptoms, but again, it is unlikely that only Syrah was planted improperly while other varieties were not.

Perhaps more significantly, over the past five years this region has experienced a significant rainfall deficit compared to historical averages. This time period also coincides with increased adoption of deficit irrigation practices by the local winegrape industry.

Additionally, the groundwater quality in many areas of the Central Coast is fairly marginal, with high salt levels. Without adequate leaching either from winter rainfall or by application of an extra leaching fraction with irrigation, these salts accumulate in the root zone and lead to increased vine water stress over time. The cumulative effect of dry winters, reduced irrigation, saline irrigation water, and increasing soil salinity should notably

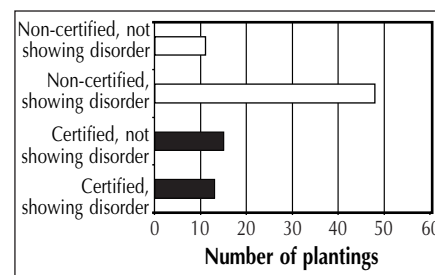


Figure III. Incidence of Syrah Disorder on the Central Coast in 2003, by planting material certification status.



Red leaf symptoms—may be an early stage of the disorder.

increase vine water stress, with all other factors being equal.

Possible primary factor

The affected areas are also characterized by extreme daily fluctuations in both temperature and evapotranspiration (ET). Daily temperature swings of 60°F are typical, and peak afternoon ET rates can be very high, driven by high temperatures, low humidity, and the strong solar radiation characteristic of the region. These factors, along with the results of some recent research regarding the unusual physiological response of Syrah to drought (discussed below), seem to suggest that excessive water stress may be a primary factor causing Syrah Disorder.

H.R. Schultz compared the drought responses of Grenache and Syrah in France and Germany.¹² He showed that Syrah, which originated in the relatively humid climate of the Rhône Valley, has a very different drought response mechanism than Grenache, which originated in northern Spain. Grenache exercised rapid and significant stomatal control under increasing water stress, which placed a lower limit on the leaf water potential attained; this is an example of “near-isohydric behavior.” This type of response is considered more typical of vines that have developed an adaptation to severe drought.

Schultz demonstrated that Syrah, in contrast, exercised very little stomatal control, instead responding to drought by continually lowering its leaf water potential while maintaining

full transpiration; this is an example of “anisohydric behavior.” Such a response may be more typical of vines that evolved where drought is rarely severe; that corresponds well to Syrah’s area of origin.

In earlier work, Schultz compared the drought response of Syrah and Grenache in France and determined that Syrah showed very little adaptive response to water stress other than lowering the leaf water potential at which leaf turgor was lost.¹³

Schultz also noted that, for Syrah under severe drought conditions, there was a very fine line between adequate production and death of a vine. A practical message from Schultz’s work is that Syrah’s drought response is efficient when water stress remains below some maximum threshold, but as water stress exceeds this, the limited stomatal response and progressively lower leaf-water potential may make the variety more prone to vascular failure (cavitation), ultimately causing a cessation in the xylem sap flow.

T. Winkel and S. Rambal conducted similar research on the varieties Carignane, Merlot, and Syrah in France.¹⁵ They also found that the Syrah exhibited relatively little stomatal response to drought. They further noted that Syrah protected its vascular integrity by reducing the total transpiring surface via a reduction in leaf area.

In earlier work, Winkel and Rambal determined that Carignane had a much greater stomatal sensitivity to changes in air humidity as compared to Syrah, which they attributed to the different evolutionary origins of the two varieties.¹⁶ They concluded that this difference in behavior reflected the recognized poorer drought adaptability of Syrah.

The degree of water stress experienced by Syrah in different parts of the world can be evaluated by comparing pressure chamber readings of midday leaf-water potential from some published research trials in other regions with values reported by Central Coast growers. Both Schultz in France and Ginestar in Australia reported maximum midday leaf pressure chamber readings of approximately 18 bars for their “dry” irrigation research treatments.⁴

By comparison, several Central Coast growers have reported midday readings of 21 or 22 bars in their vineyards. Research by C.G. Dundon and R.E. Smart in Australia measured values of up to 23 bars prior to harvest in a dry-farmed Shiraz vineyard. According to the authors, “extraordinary levels of stress were experienced by the vines” at this site, which led to a substantial amount of leaf necrosis.²

Based on the above research, the drought-response mechanism of Syrah appears to make it prone to xylem cavitation and/or leaf-area reduction when under excessive drought conditions. Such a response could then manifest itself as the symptoms that we associate with Syrah Disorder on the Central Coast.

Growers have commented that the onset of symptoms often occurs very rapidly, with entire vines becoming severely affected within just one or two days. This type of response is consistent with a significant and rapid change in vascular function, particularly at some location lower on the trunk.

Interestingly, research by ENTAV in France has shown that Syrah tends to form fewer vascular connections between the rootstock and scion after grafting as compared to Cabernet Sauvignon and Grenache.⁶ If this trait remains as vines mature, it could predispose the variety to vascular failure when under severe stress.

Growers have also noted that individual vines that are affected in one season may not show symptoms the following



Red-brown leaf symptoms—may be a more advantaged stage of the disorder.

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Poor training of young vines can result in constriction of the trunk, which will ultimately cause red leaf symptoms and stunting.

season, and vice-versa; thus vines can recover from the disorder, which would also be expected with a transient vascular failure.

From a practical irrigation management perspective, the anisohydric drought response of Syrah effectively masks the degree of water stress experienced by the vines. By lowering its leaf-water potential while keeping its stomata open, Syrah maintains relatively strong leaf turgor pressure and continues to transpire large amounts of water, which keeps the leaves cool and the photosynthesis rate high.

The resulting firm, cool leaves and continual growth suggest to growers conducting visual and tactile inspections that the vines are not under significant stress, when in fact just the opposite may be true. Additionally, with its open stomata, Syrah will be transpiring relatively more water than other varieties under drought conditions, effectively removing more water from the soil and ultimately worsening its own condition.

The demonstrated varietal susceptibility to severe drought, recent dry winters, reduced irrigation amounts, marginal irrigation water quality, and the intrinsic climate of the inland areas of the Central Coast, in part, may explain why we have seen an increasing incidence of Syrah Disorder in this area in recent years.

However, the fact that many of the recently affected vineyards have, in the past, produced high quality grapes without showing any disorder-symptoms suggests that this is a transient and correctable phenomenon. Growers with susceptible plantings should consider paying extra attention to irrigation and salinity management practices to avoid severe vine-water stress, and ideally monitor vine-water status throughout the season with a pressure chamber.

While other as-yet unknown causal factors may be involved in this disorder, the pattern of occurrence on the Central Coast suggests that excessive vine water stress is a primary factor in its ultimate expression.

Future plans

Our 2002–03 Syrah virus survey did not find Syrah vineyards with symptoms that matched the French Syrah Decline symptoms. In general, the majority of Syrah plantings are relatively virus-free compared to varieties, such as Cabernet Sauvignon, Chardonnay, and Zinfandel, all of which have been established in California longer.

Over 1,500 PCR tests were completed on 131 samples from 77 surveyed vineyards. Approximately 95% of the samples tested negative for viruses typically associated with graft union disorders. Virus testing results were very similar statewide, which would be expected since the same clones and selections are available to all of California's growers, and viruses usually move with propagating materials.

The majority of problem sites could be explained by vineyard site or management issues. At this writing, Syrah growers should be relieved to know that if Syrah Decline exists in California, it is very rare.

Authors Golino and Rowhani had the opportunity to visit French vineyards with Syrah Decline. The French cases did not resemble cases in California. The swelling at the graft union of vines with the French Syrah Decline syndrome is solid and woody — something which has not been seen in samples of Syrah submitted to us from California.

We continue to take an interest in the cause of the French Decline problems.

We are collaborating with Dr. Jean-Michele Boursiquot, ENTAV, France, and his colleagues to investigate the possibility that an unknown virus is causing French Syrah Decline.

Because we are not convinced that authentic Syrah Decline has been found in California, we plan additional work with samples from France that are frequently identified to demonstrate Syrah Decline. Both French samples and California field samples will be used for dsRNA extraction and cloning in hopes of identifying a causal agent of Syrah Decline.

Extracted dsRNAs can be virus-specific and are often used to find new viruses in plants, including grapes.¹¹ If a dsRNA can be associated with Syrah Decline, it can be used to create a cDNA library, which can be used both in detecting the agent of disease (by developing reliable PCR primers) and in characterizing its genome.

Grafting experiments are ongoing to try to recreate the symptoms of Syrah Decline. We have established a small field trial with symptomatic Syrah grafted onto select rootstocks to attempt to induce observed symptoms.

Most critical in our opinion, new work needs to be initiated on the Central Coast to determine the cause of the widespread and economically significant Syrah Disorder. Water-relations



Budding tape should be removed from all young vines as soon as the graft is healed, to prevent overgrowths like the one shown here.

research noted earlier provides a solid direction to pursue in the 2004 season.

A proposal has been submitted to conduct a thorough investigation into the water relations of Central Coast Syrah across a range of irrigation levels, to determine if the disorder symptoms are, in fact, correlated with increasing water stress.

Plantings of Syrah along with Cabernet Sauvignon as a comparison variety will be monitored periodically for leaf- and stem-water potential, stomatal conductance, and leaf chlorophyll content. Vines will also be monitored continually for trunk sap flow, leaf temperature, and soil moisture.

A primary goal of new research will be to find a measurable vine parameter that can be used practically to predict if and when the vines are approaching the onset of the disorder.

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Many growers on the Central Coast have shared their individual experiences, theories, and valuable time in helping us evaluate Syrah Disorder, and a group of proactive Central Coast growers has pledged additional funding to the

American Vineyard Foundation specifically to address this issue. Our thanks to all for giving us the help and resources needed to effectively address this emerging issue. ■

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