FROSTS AND VINES IN THE UNITED KINGDOM

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Abstract.

Vines are normally very hardy plants that, with the right breeding, will grow in many different climates. However an apparent increase in the occurrence of extremes in regional weather patterns, has resulted in many established vineyards having to take expensive precautions, especially against late Spring frosts. This paper examines the effect of frosts on vineyards in Britain and outlines some of the methods that have been used to combat them in recent years.

Introduction

In the current century, May frosts have seriously hit vine production on several occasions. Linch Hill in Oxfordshire recorded losses in growing buds as:

2012: 50%
2016 50%
2017 30%
2020 100%

To quote Ian Fleming's character Goldfinger '*Once Mr. Bond is happenchance, twice is coincidence, three times is enemy action*'. We have had four frost events in 10 years so maybe we have a trend that requires serious thought.

With Britain's increasing plantings, viticulture has gone far beyond the occupation of eccentrics and hobbyists and now classifies as a growing industry. Large sums of money have been invested in plantings and wineries, and massive losses stand to be made if late frost continues to be a regular occurrence. The problem is exacerbated by early budburst caused by warm conditions in early Spring. In 2020, over 300 vineyards reported budburst before mid April and it is this growth that was vulnerable to the late frosts.

Above: Damage at Linch Hill, Oxfordshire on 12th. May 2020

What causes the damage?

As with most living organisms, the grapevine contains a high proportion of water. If the temperature drops below the freezing point of this water, it will freeze, form spikes of ice, and these will puncture the cell walls, so killing the cells. Most frost damage on grape vines occurs near ground level where, at night, it is much colder a few feet above the ground; so protecting the trunk of the grape vine in very cold climates is imperative. This is especially important during a cold, still, clear night when heat is radiated rapidly to the atmosphere and the temperature near the ground drops dramatically.

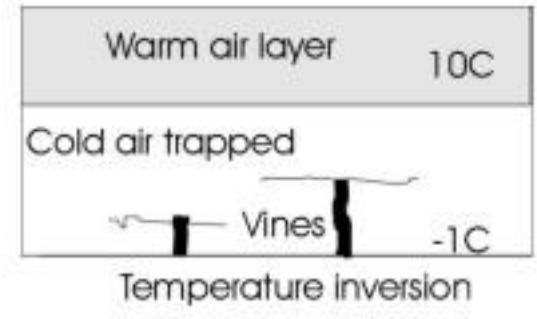
Some years ago, a party went round Mike Roberts' Ridgeview vineyard in Sussex, where frost is a problem. Mike's solution at that time was the "Bougie"- a giant candle (see photo) that is lit when frost threatens, and which sends black smoke into the vine rows. One problem was that they were expensive and were therefore lit only when frost was certain. This involved close monitoring of the weather forecast and, on suitable nights, sitting around with a large supply of coffee in case the temperature gauge dropped sufficiently. Then, there was a rush round the vineyard in order to light all the bougies. There was also one other vital step at Ridgeview. This involved ringing up nearby Gatwick airport and telling them that the lines of flaming beacons were NOT a new flightpath marker. The thought of a Jumbo jet gliding down onto the vines does not bear thinking about. Peter Johnson, when at Offa's vineyard on the Welsh Marches, used to use barrels with engine oil in them, which were set alight when frost threatened. Local farmers, seeing the resultant smoke, used to comment that '*that mad vine grower is at it again*!'

Types of Frost:

Advection frost occurs when a dry, cold air mass moves into the area, driven by a northerly wind. In hilly areas, the cold air can 'slide' down the hillside and freeze the land in a valley. Such movements are known as 'Katabatic winds' [(1)] There does not seem to be a lot that air-stirring machines can do under such conditions but barriers across known draining lines can help deflect the flow from the vineyard. Frost hollows do occur in Britain [(15),] -Rickmansworth and the Chipstead Valley in Surrey being noted examples. In 2012, the temperature at Chesham reached -18.3C. with air draining from surrounding hills. In the Breckland of Norfolk, cold air can stagnate and prevent the mixing of air resulting in low and continuous ground temperatures.

Ground Frost is defined as when the temperature at ground level falls to $-1^{o}C$ or less and the dew freezes and damage low buds and leaves.

Radiation frost occurs when a cold windless air mass settles over the area, with clear skies. The ground freezes as the warmth in it rises. Because there is no wind, a '**temperature inversion'** occurs, with a layer of warm air about 50 feet above the ground, trapping the cold air under it. Cool dense air is trapped near the ground, affecting the vines.



Hoar frost

The white crystals seen on the grass on a cold morning are neither a ground nor an air frost. This is a 'hoar frost', which forms when the air cools and water condenses onto the grass

The actual temperature at which damage will take place was and recorded in an article on eVineyard [13] They found that dormant buds will survive at temperatures down to -20C, while, once beyond bud swelling, they are much more sensitive. The average figures discovered were:

Growth stage	10% damage (°C)	90% damage (°C)
First swell	-10	-19.4
Full swell	-6.1	-12.2
Bud burst	-3.9	-8.9
1st leaf	-2.8	-.1
2nd leaf	-2.2	-5.6
3rd leaf	-2.2	-3.3
4th leaf	-2.2	-2.8

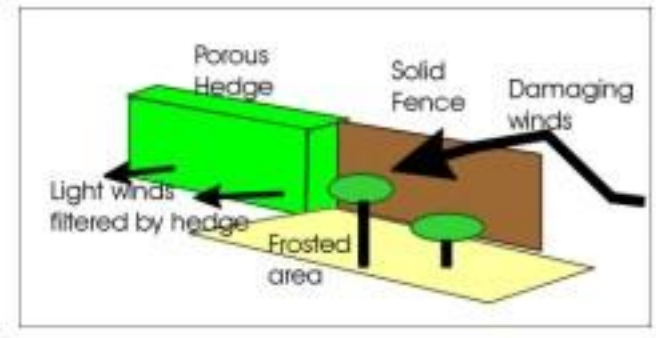
Frosting at Ludlow Vineyard, Shropshire. 13th May 2020

Prevention

1. Site selection

Opinions vary about prevention methods- an Internet site for Western Australian Viiticulture [(4)] suggests that the vineyard site should be carefully chosen. This boils down to the old marketing adage- "Location, location, location". Some owners take great care over this. Leventhorpe was chosen because it was a 'warm field' and rarely suffers frosts. Wroxeter too rarely suffers frost damage. Anyone choosing a new site should look at the following factors:

a) **Landscape** - Closed valleys can trap cold air and create a thick frost zone while open plains tend to thin the frost layer. Where radiation frosts are common vineyards should be designed so that cold air may drain away from the vines. A 2% fall along vine rows with no barriers to airflow is considered ideal Barriers to airflow include windbreaks, plantations, trees along creek lines, dam banks and buildings. Fog is a good indicator of cold poorly drained areas where radiation frosts could be a problem.
b) **Soil types** - Dark soils absorb more heat than light soils while gravelly soils absorb more heat than clay soils. If close packed and well mown, they may retain the heat.
c) **Windbreaks** - Windbreaks restrict airflow and can trap cold air of a radiation frost. Frosts need to be considered when windbreaks are selected and located.
d) Choose **an appropriate site** and use what frost prevention methods are suitable for it. Solid windbreaks (e.g. walls) tend to keep in the frost, but hedges and trees should keep in the heat. I note that in our garden, the wind filtering through the trees usually keeps the frost away. One section of the trees was heavily trimmed and the builder next door put up a wooden fence across a third of the hedgerow. In that area, the wind comes over it, causing damage to the fruit buds at a higher level and allowing frost to form on the ground. The rest of the hedge, without a fence, is far less prone to frost.



2. Vine selection

Vines change their cell content in winter in order to acclimatise. Some varieties are more efficient than others. After veraison, carbohydrates concentrate in the fruit clusters and shoot growth slows. As temperatures drop, water-impeding substances are deposited in the vine tissues to slow the flow of water through the vine. The canes turn from green to brown. The less the water content in the cells, the less likely that they will freeze. However a sudden deep extended frost could supercool any remaining water. If this occurs in early November before the vine is fully ready for the cold, the water content will still be high. The inter-cellular spaces can accommodate some of this so damage will be slight. However, if temperatures remain very low, then this supercooled

water will turn to ice, expanding its volume by about 9%. The cell walls stretch and then break.

Some vines are better than others at coping with cold weather. Riparia and Amurensis are good at preparing for winter, but can interpret brief January warm spells as the arrival of Spring, so may suffer damage in February. Vinifera is slower to prepare for winter, but, like sensible humans, equally slow to accept that Spring has arrived. (never cast a clout till May be out!) The Canadians have carried out extensive research on winter-hardy hybrids that combine the best of these features.

3. Passive methods.

The FAO [10] advise removal of ground cover in order to improve the ability of the ground to absorb heat.

'For passive frost protection, it is better to remove all vegetation (cover crops) from orchards and vineyards. Removal of cover crops will enhance radiation absorption by the soil, which improves energy transfer and storage. Cover crops are also known to harbour higher concentrations of ice-nucleation active (INA) bacteria than many orchard and vine crops, so the presence of vegetation on orchard and vineyard floors increases the INA bacteria concentrations on the crop and hence the potential for frost damage.

4. Post-planting methods

a. Heating the vines: a report from Australia [3] suggests trailing electric cables round the vines in order to raise their temperatures by one or two degrees, and so preventing the buds from freezing. Associate Professor Dr David Lamb says the system first appeared in France, but has never been tried in Australia. "*We have established two one hectare trials with panels of vines subjected to different heating treatments with this electric cable and our aim is to do a systematic evaluation of (a) - does it really work and (b) - if it does work, what's the most effective way to set it up and how much will it cost the growers, and is it cost effective?*" he said.

The effects of the cables on a 2Ha block of Sauvignon Blanc, after a -3C frost were as follows.

Non-heated vines. 41% capful loss
Low heat 28% loss
Medium heat: 16% loss
High heat 13%
The power requirement was estimated at 43Kw/Ha in a small vineyard

The main problem that he foresaw was the possibility that the cables could be accidently cut (apart from a power loss at a critical time- Sod's law!)

A number of vineyards in Britain are using such electrical systems to prevent frost damage. Gaia Systems [8] have a system where the cable is wrapped around the fruiting cane, and the heat is then conducted into the sap of the cane. Because sap is a good conductor of heat, it is able to evenly distribute this to the new growth internally; with similar cable systems used on Champagne, France. Several years ago, Duncan Sangstar, Director of Designer Climate Solutions NZ, developed purpose built cables for frost protection trials in and around Cromwell, New

Zealand. This is currently being used at Ridgeview and at Winding Wood in Berkshire where , according to their web site[7] *'they were hit with the worst case scenario at the end of April 2017, of early shoots (an average of 3 leaves out), and 3 nights of -4.5ºC conditions. Owner Christopher Cooke describing it as the "April Armageddon". Our system offered exceptional protection on the first 2 nights. The 3rd however was a perfect storm of hail and rain in the early evening with northerly winds, followed by –4.5°C temperatures overnight. Even so 30% of the crop was saved.* ' Goodworth Clatford vineyard in Hampshire also use them and reported that

"*We have heating wires throughout our one acre vineyard, laid in ten circuits. Expensive to install, but cheap to run (and requiring no departure from our beds in the small hours!) On the 13/14th April, shortly after bud burst, the temperature fell to -3C overnight. 90% of our rows were totally unaffected, but the buds on the other 10% were almost completely destroyed. Then we discovered that the circuit switch covering the damaged vines had tripped. Annoying - but this black and white (or more accurately green and brown) evidence of the effectiveness of the system did encourage us to believe that the investment had not been totally in vain*." They also discovered that while the wires worked when the buds were close to the wires, the system was effective. However, when the frost came late, and the buds/leaves were about 6 inches from the wires, the frost damage was considerable. They are experimenting with a fleece wrapper over the buds, so that the wires will provide heat within a cocoon.

b. Training Research in New Zealand (1) emphasises the importance of the correct training method.

"*There is a greater risk of frost damage the closer the buds or shoots are to the ground. Trellising systems such as Te Kauwhata Two Tier whose bottom cordon wire is 0.4m from the ground and Scott Henry whose bottom cordon wire is only 1.0m from the ground and the shoots are trained downwards have a greater risk of frost damage. Trellising systems such as Smart-Dyson whose cordon wire is 1.2m from the ground and Vertical Shoot Positioning whose bottom cordon wire is about 1.0m from the ground but the shoots are trained upwards have a lesser risk of frost damage*". Trought et al [1] calculated that at Cromwell in New Zealand, vines on a 2m high trellising are 3.96°C warmer than those on the standard 0.9 m and 7.2°C higher than at ground level." In the upper part of Leventhorpe vineyard, Lenz-Moser training t

High-wire Lenz-Moser training at Leventhorpe

c. Vine pruning burning One Australian vineyard commented "*pruned cuttings are dropped at the end of the rows. They are then collected and burned, especially on the coldest nights when the vines are threatened by the cold. Any unused ones can be used for barbecues".*

d. **Frost Buster** Bob Lindo of Camel Valley uses a Frost Buster. This can prevent the awful effects that frost can have on the fruit bud. The machine works by burning gas to provide a heated air supply, which is then blown by a large tractor driven fan, across the orchard or down a tunnel. Iowa University research [2]

suggested that to be effective, such machines should be started up before the temperatures dropped before freezing. It also noted that '*Depending on the field layout, a single large tower machine will protect up to about 10 acres with a 10 degree temperature inversion differential at 50 feet*.' Where there are contour differences in the land, flow directional heads are needed. These machines carry a number of gas cylinders and are now increasing in popularity. In 2020, Nyetimber had about 20 machines and had little or no damage as a result.

e. Sprinklers: William Booth at Mill Lane vineyard in Lincolnshire has water sprays ready in case of frost. Advice from Iowa State University is that the sprays should be low down, to prevent too much ice building up on branches and snapping them.
Gerry Garner [(6),] the UKVA spray expert in 2013 had doubts about sprinklers. He commented: "*Spraying water only works if you are set up with permanently positioned frost sprinklers. The vines would become coated in ice (which might prove a bit heavy for the trellis!) but provided water is always present the temperature cannot drop below zero. If you stop the water before the air temp is above freezing, the ice will continue to cool to sub zero temperatures. Obviously this requires expensive sprinkler system, good water supply and free draining soil.*
The spray-on treatments such as Anti-Stress and FrosTec are believed to give protection from light frosts but need to have been recently applied or new growth will be unprotected. At one time various giant candles and simple oil or propane heaters were used for orchard frost protection but current oil prices plus attitudes to global warming and air pollution killed that approach. Paul Sibley at Bosue used Zenith this year, and despite being in a frost pocket, had little loss.
Experience in Champagne showed that spraying works, but is expensive in water- a hectare of vines requires 50 cubic metres of water to coat the vines with sprinklers based 15-20 metres apart. John Lilley at Congham vineyard in Norfolk also uses sprinklers successfully. He commented that '*We have now had 3 or 4 nights when the temperature has been in the range minus 3 degrees to minus 5 degrees here in North West Norfolk .*
We essentially have no frost damage because we irrigate overhead continuously overnight and apply about 2mm. per hour of "rain" in a strip down the rows about 800 mm wide to ice up the soft growth . Running costs are about £5 per acre per night and the system is capable of being controlled from a simple temperature sensor in the vineyard.
The only damage we have had this year is where a couple of the sprinkler heads got blocked . '

Of the vineyards reporting problems, 40% of them successfully used sprays, including Congham (picture below) but of the others, 5 vineyards loss more than half their crop.

Sprayed vines during icy conditions at Congham, Norfolk. There was minimal damage.

f. Bougies. These are large candles which can be lit when required. To do so requires a good warning system, usually from a computer based App. These also require labour standing by to light them and, once used, need replacing. Most vineyards in the South east used them, and used them successfully. However, of those actually reporting, there was mixed success. In appendix 2 there is a comment from a Bougie producer on the re-usability of bougies. Their main comment was that if extinguished, they could be used 3 times.

Bougies in the vineyard at Albury Vineyard , Surrey

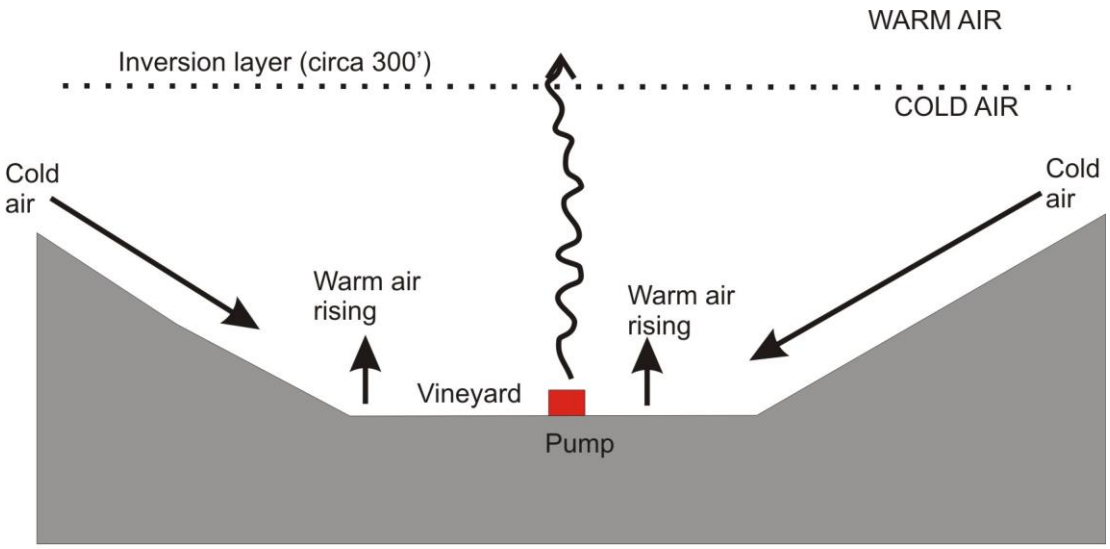
- **g.** A company in New Zealand has developed a frost fan mounted onto a trailer, which is available in the UK. It requires no planning permission, as it is not a permanent structure. It creates the same noise level as a fan assisted sprayer – trials have shown it to be inaudible at a distance of 300 meters. One machine protects between 8 – 10 acres depending on the topography of the site. The company claim that it will protect 5.5Ha and can be left unattended overnight. The **Tow and Blow** works by capturing the heat rising from the soil and blowing it back into the vineyard, ensuring ground temperatures then are not cold enough for frost to form. The ability to angle the fan brings flexibility for vines grown on hilly areas. In 2020, it was successfully used by Tuffon Hll vineyard in Essex. Claims by one company are that the fan will protect
  - 4 hectares of land down to -3°C
  - 3 hectares of land down to -4°C
  - 1 hectares of land down to -5°C

Another company listed the benefits as:

- Protects up to 5.5 ha
- 30 hp diesel engine
- Fuel usage 5l/hour
- Auto start and stop
- Can be left unattended overnight
- Safety feature meaning fan can only operate when the boom is locked in the raised position
- Fan can rotate and oscillate to cover a wide area
- The shrouded fan ensures airflow, velocity and volume are maximised
- No planning consent or installation required

A quotation given to one UK vineyard in October 2020 was for £25,000 plus delivery. This is probably out of range for very small vineyards, and its effectiveness will depend on the layout of the vineyard. Where vineyards are not rectilinear, then additional fans could be required. Apparently, government grants MAY be available.

An American Company produces an air pump called **JackRabbit** which works with Radiation Frosts. It pumps cold air upwards to the Inversion layer, and so mixes the air.



Radiation frost

On a clear night, warm air rises and cold air sinks down slopes to the vineyard The pump blows this cold air upwards to the inversion layer where it mixes with warm air. This allows warm air to replace it and prevent a RADIATION FROST

g. Another approach is to hire a **helicopter** to fly to and fro over the vineyard at low level, the downdraft mixing the warmer upper layers of air with the cold air at ground level - expensive and the neighbours will love you! In New Zealand, one vineyard owner in Canterbury estimated the cost at $700 to $800NZ an hour in 2010 [(11)] He used 8 helicopters. In the Médoc, the 2019 saw severe frosts and at Château d'Arsac, 3 helicopters were also used in conjunction with fires [(12)] to protect the vines from late frosts. "*We had to do it*," Philippe Raoux, owner of Château d'Arsac, told news website 20 Minutes. *"At 6:22 this morning [Sunday], it was -2°C and the three helicopters did their job well, even though the effectiveness of the operation will not be measured for three to four days." [(13)]*
Two years ago, the estate lost 90% of its harvest when five days of frost ravaged vineyards across large parts of the country." (Château d'Arsac 2016 sells for £280 a bottle.)A comment was that it only works with advection frosts, where there is warm air available to circulate.

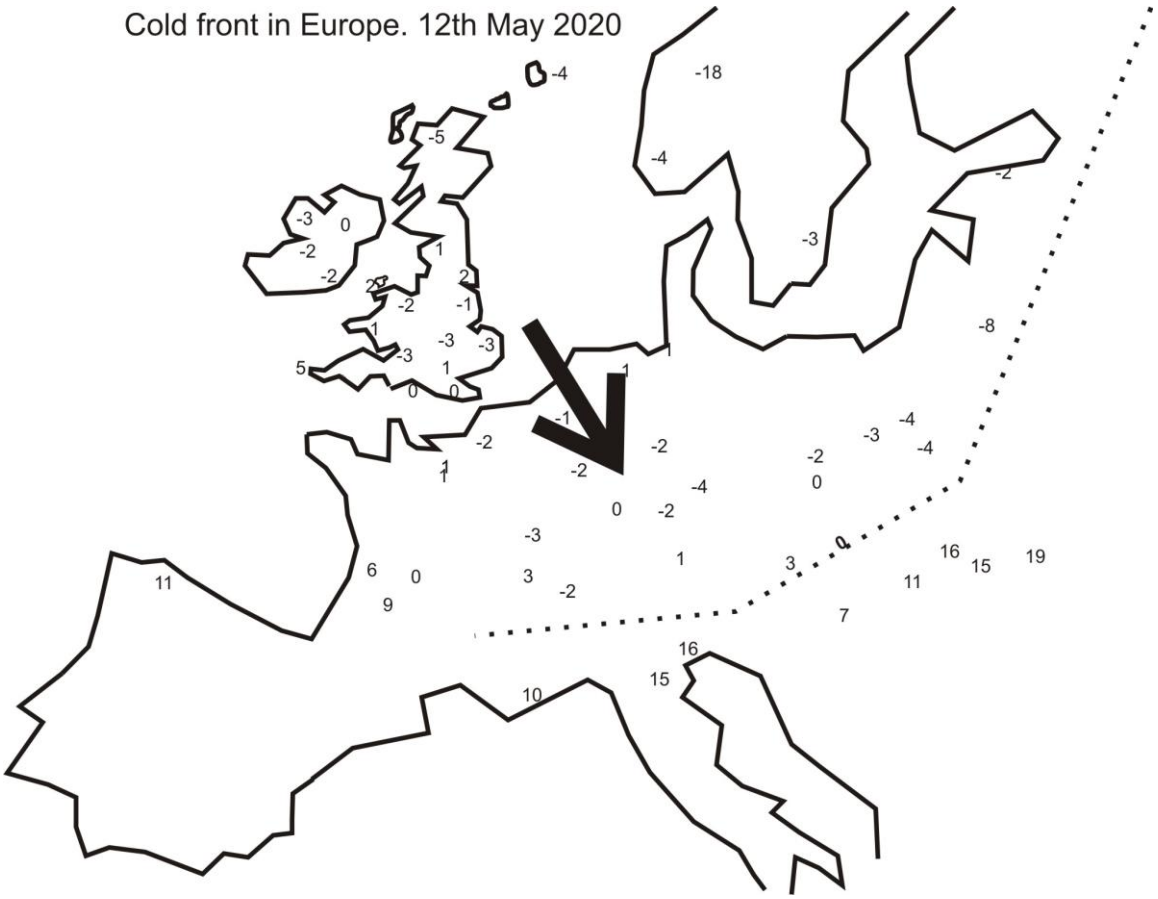
Other methods

Prevention methods and site selection are all important, as are the local weather conditions, which are not latitude dependant. Yorkshire vineyards thrive happily if reasonably sheltered, Lancashire, being very exposed to westerly winds, has no commercial vineyards while Underscar Manor , further north in Cumbria, has one that is in a sheltered location. Quebec vineyards have to bury their vines in winter, or develop vines that will survive down to minus 35^{o}C, (7) to prevent serious damage. This method has been used by a small vineyard in Braemar, Scotland.

Kennedy and Pecchenino [(9)] recommend keeping the area between the vines well mown, with loose soil. *"Loosely cultivated soil or deep inter-row herbage provides an insulating layer on the soil surface that will restrict heat absorption during the day and restrict the ground's ability to re-radiate heat out during the night*". They also suggest late spur pruning to delay budburst and raising fruiting wires. They found that every 100mm the wire is above the ground increases the temperature by 0.2^{o}C. Smyth and Skates [(5)] noted that passive frost protection (i.e. expecting the dark soil to radiate enough stored heat a

night to provide protection) is often inadequate, even though they found that there is sufficient solar energy available, if it could be stored. They have tested black solar-powered quilts which collect solar heat and give it out at night. They found "*under certain site conditions, the solar quilt frost protection system has been shown to provide a significant increase in the localised air and soil temperatures adjacent to the vine trellis during frost events*."

Experiences in 2020 with prediction software



In 2020, major frosts were predicted for mid May as a cold front (shown as the dotted line) swept down from Iceland in a south-easterly direction. These brought sudden low night temperatures which struck with devastation effect.. Some prediction apps predicted the night correctly and allowed vineyards to take precautions. Many were caught out. Dunley in Hampshire were unlucky, with 50% destruction, despite their climate app having predicted positive temperatures. Poulton Hill at Circencester were similarly affected. Southcott in Wiltshire had 95% hit from ground frost and Durslade in Somerset were totally wiped out as were Kerry Vale in Shropshire and Daws Hill in Oxfordshire and 18 others. Elysian Fields in Cambridgeshire were affected, despite temperatures there not falling below +2^{o}C. Several vineyards have their own weather stations, but these do not always have prediction features.

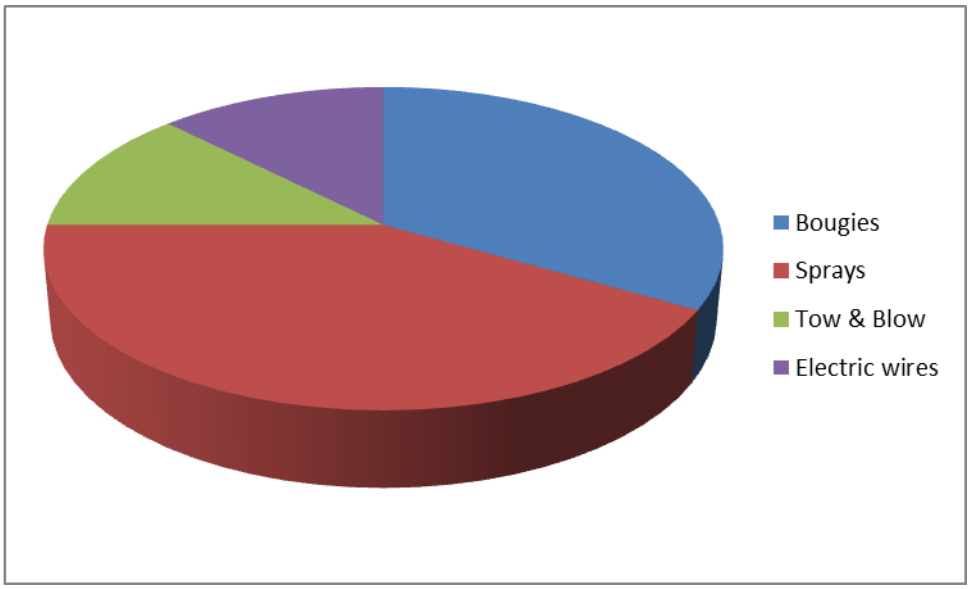
Note: This does not contain all the reporting vineyards- many of those reported <20% loss are not included. My thanks to Stephen Skelton M.W. for providing some of the statistics in his survey of Frost damage

Some vineyards tried *Climatevine.app* and found it underestimated the problem though others, such as Ludlow and Swanmore found it 'bang on'. Albury used *Metcheck*, but found 5°C variations within the vineyard. Mike Hardingham at Ludlow commented on the variation between vine types. "*Here in Ludlow, one day the Solaris was a sea of green, the next day it is all brown again! Interestingly, the Seyval in the other half of the field was not affected nearly so badly*." What is clear is that the apps while helpful, are not 100% reliable. The belief was that the failure of the app could be because of variations within a postcode area. They are also only a predictor, not a cure. They only say when precautions need to be taken, not what precautions to take.

Bob Neilson at Brightwell commented that '*Have found that within 24hrs the uk metoffice has been the most accurate (it predicted -3 for Tuesday morn when most other sites said -1). Not too surprising given it has the most 'actual' reporting sites and recording staff in the UK. Many of the others forecasters aggregate and computer predict without real measurements. Beyond 24hrs metoffice gets less accurate*. '

Use of other hardware

In May, 2020, few reporting vineyards used any hardware or sprays, and the majority of those reporting serious losses. Of those reporting, Ridgeview, Albury, Burges Field, and Chilworth Manor used Bougies and reported less than 10%. Only one vineyard used them without success. A tow and blow system was used at Tuffons Hall in Essex and appears to have been successful, with less than 10% loss. Sprays certainly worked when accompanied by temperature sensors. One vineyard tried covering the vines with netting, but this had no effect. Of the reporting vineyards, the proportion of systems used was as shown on the pie-chart. Sprays may include both pre-frost sprays and continual overnight water-sprays.



Is prevention worth the expense?

Many people have installed Solar Panels with only a vague idea as to whether they will repay costs, especially as the British Government have reduced subsidies on newly installed ones. From my own experience, if the initial expense is written down, then I am currently living on free electricity. The cost of electrically driven systems could be balanced against installing a small solar farm. In Australia, the expense is definitely seen as being worthwhile. CSIRO (the Australian National Science Agency) research suggests that Australia, despite a warming rate of 0.178^{o} per decade since 1960, has seen its frost season length increased by 26 days , thus increasing the risk to vines. Parts of the Champagne region of France lost up to 50% of its crop in 2017. Claiming this is a 'once in 100 year event', as Insurance companies (and governments) have a habit of doing, still does not remove the statistical possibility of a lot more such events. We have seen serious frosts in 2013 and 2017, and most recently in May 2020. The latter was especially serious as over 300 vineyards had seen budburst over a month earlier, so any crop will come from secondary buds (or not at all).

While the method used is obviously site specific, and not all systems have anywhere near 100% success, the question is not so much the cost of installation and running costs are, but rather how much loss can each vineyard sustain at, say, 3 year intervals, and still be viable.

Linch Hill vineyard a week after the frost, with temperatures in the 30Cs

References

1. Trought, M.C.T., Howell, G.S, Cherry, N Practical Considerations for reducing frost damage in vineyard, at .net.au/news/newsitems/200610/s1776629.htm
2. Domoto, P. Frost Prevention for Fruit Crops Jan 2006 Iowa State University
3. Vine Heating may eliminate frost damage. ABC News Online 30th Oct. 2006. Dept. of Agriculture & food, Western Australia. Frost Prevention and Protection in Vineyards. Sept 2005 .
4. Smyth M & Skates H, 2009. A passive solar water heating system for vineyard frost protection. Solar Energy 83, pp 400 – 408
   (Also published in Grapevine No 26 Summer 2006)
5. Garner, G. Email to Vinelist April 2009
6. Plocher, T and Parke,B. northern Winework- Growing grapes and making wine in Cold Climates. Northern Winework Inc.2001
7. Winding Wood Vineyard story on their website at windingwood.co.uk
8. Gaia Systems at www.gaia .co.uk
9. Andrew,R & Pecchenino, D Frost Control in New Zealand Vineyards
   Published by New Zealand Winemakers 2014 @ Nzwine.com/media/13891/frost-control-low-res.pdf
10. Frost Protection: Fundamentals, Practice, and Economics United Nations Food & Agriculture Organisation
11. Helicopters hover over vines to keep frost at bay stuff.co.nz/the-press/news
12. French winemaker's extreme measure to protect crops. Connexion France/french-news
13. How to prevent frost damage. eVineyard @ evineyard.com/blog/2019/07/03
14. My vines have been frosted- what now Agriculture Victoria @ agriculture.vic.gov.au/agriculture/horticulture/wine-and-grapes
15. Julian Mayes. Regional weather and climates of the British Isles. Metrogroup UK. A rmetsonline.wiley.com

Appendices.

Four months after the frosts, viticulturalists were asked how they had treated the vines after the frost, and whether they had actually managed to get a crop. The main responses concerned that most hardy of grapes, the Seyval Blanc. Even with this the general opinion was that a very small and late crop might be obtained, it was probably best to leave them alone until next year.

One other response concerned the frost-prevention measures. Wind-generators and electric wires could obviously be used year after year. However bougies, while popular, have to be replaced.

Appendix 1 – Post frost reports

As you know we had a 100% wipeout amongst all three of our varieties. Secondary growth appeared on all vines a few weeks later and the frosted shoots and leaves turned to brown "crisps" in the May sun and eventually dropped off.
We removed all the fruiting canes from our Phoenix and Rondo to concentrate the growth into the crown to get good strong canes to tie down for next year. This strategy has worked well and the vines are looking good and healthy. The odd bunch of grapes also formed but we removed them.
With the Seyval blanc, we experimented with leaving the fruiting canes in place but removed the weaker looking secondary shoots that appeared. We did get some bunch formation, but they were very few and clearly weren't going to ripen in time, so we removed them. The cane growth from the crown is not as strong as we hoped so in retrospect, we probably should have removed the fruiting canes at the same time as the Rondo and Phoenix – and this is what we'll do if (when!) we get frosted again.
We've been summer pruning as normal keeping the canopy open and haven't sprayed at all this year. No signs of any disease.
Linch Hill, Oxfordshire

Breaky Bottom had a bad frost in mid-May – the first real frost damage in over 40 years of cropping!! Can't complain……
It was a very special frost because vineyards like Mount Harry, Offham, did not suffer any damage – usually any inland vineyards would show severe damage before Breaky Bottom – very strange…..
I estimated 80% loss and Stephen Skelton was here last month and confirmed he had never seen such frost damage in any vineyard (40 + years!!) Any secondary buds which produced flowers and set look far behind and furthermore the extension shoots with these secondaries have only grown 1 - 1.5 foot…….great lack of foliage /photosynthesis and sugars will be very low, probably un-harvestable.

Painters Hill Vineyard reported that "we are quite high altitude (116m above sea level at the top of the vineyard) and suffered 95% frost damage. Our vines are all Pinot Noir or Seyval Blanc.

Both varieties recovered well in terms of growth (lots of replacement canes from around the "fist", now very vigorous, causing a lot of work for us), but the PN grapes are very thin, and mostly still no veraison (a few bunches have, closest to the trunk). We'll be lucky to get 1.5 tonnes/ha equivalent from them.

The SB has recovered far better in terms of number and weight of bunches – about equivalent to an average year (say 5-6 tonnes/ha). But again, no veraison yet.

I'm now very worried that we may never get to a satisfactory ripeness or sugar level before the end of the growing season. So very late harvest (end-October or early November) or no harvest at all, depending on whether we have an Indian summer?"

Bearley (Worcestershire)We reported to you that we had lost virtually 100% of our young shoots on May 12th. We saw good recovery after the previous frost in 2017 and took in an excellent crop. This year is very different. Pinot Noir Précoce 0% recovery, Regent 5% recovery

and Seyval about 30% recovery. However, as the Seyval is on secondary growth and is a very late cropper anyway, we are doubtful as to whether they will ripen before the first winter frosts.

Appendix 2 - Bougies

Is a bougie refillable? Good question. The 12-hour crop Candle will protect you for at least 3 frosts. The crop candles are a good insurance against Frost. If you don't get a frost or only get one next spring you you will be lucky, the good thing is you will still have the Candles at the ready as the shelf life is 5 years. The only thing we cannot do is have them refilled but we are looking into the cost of this and a recycling alternative.
Other Bougies have an 8 hour burn and sometimes are over filled making the wick difficult to light. We have talked to over 300 vineyards managers and listened to what they need from Bougies. Our Crop Candles have been tested and tried by several Vineyards. We have also provided the WineGB sustainability program with our CO2 fuel testing report in accordance with their guidelines. We are providing the U.K. orchards and vineyards with an alternative option for a better product and more cost effective than existing "Bougies". Our new 12-hour burn 100%. Vegetable wax Crop Candle fits the needs of U.K. growers. This is our first year and we will continue to invest and develop our product to give U.K. growers what they want from The Crop Candle Company. (From a bougie supplier website)