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Winegrape Cultivar Trials in Connecticut: 2012 - 2015

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In the past 15 years, the number of wineries in Connecticut has doubled (32 extant) while the number of vineyards (44) and the total acreage planted to winegrapes has tripled (450 A). This burgeoning industry, a form of agro-tourism, brings economic benefits to the rural communities in which most are located. Although Connecticut is geographically a small state, minimum temperature in winter varies from 0° F near the coast to -15° F in the Litchfield hills. The major limitation for the kind of grape that can be economically grown in this area is the survival of grape vines through the winter. Another problem is the length of the growing season, which may be too short to allow late season cultivars to fully ripen. Vineyards are expensive to establish (~$5500 per acre) and maintain (~$2700 per acre annually) and do not produce salable product for, at least, three years. Thus, it is of paramount importance to choose the "right" cultivar when planting a new vineyard. It is also very important to choose the proper training and pruning method according to the habit of growth of each cultivar.

In 2008, as part of a multi-state project funded by the National Institute of Food and Agriculture (NIRA project NE1020: Multi-state Evaluation of Winegrape Cultivars and Clones), the late Dr. William R. Nail, assisted by Ms. Joan Bravo, planted thirty one cultivars of winegrape at two CAES research farms (Lockwood Farm, Hamden CT and The Valley Laboratory, Windsor, CT). Cultivars were chosen, in order to reflect the great variation in climate over the state of Connecticut, spanning the entire range of climatic preferences.

Table 1. Winegrape cultivars planted at Lockwood Farm (Hamden CT) and The Valley Laboratory (Windsor CT). The GS column signifies **G**rowing **S**eason climate preference [cool (C), warm (W), or hot (H)]. The DS column signifies **D**ormant **S**eason climate tolerance [mild (M), cold (C) or very cold (VC)] [* indicates cultivar is planted at both sites]

<table>
<tr><th>CULTIVAR</th><th>GS</th><th>DS</th><th>TYPE</th><th>COLOR</th><th>SITE</th></tr>
<tr><td>Pinot Blanc</td><td>C</td><td>C</td><td rowspan="14">VINIFERA</td><td rowspan="6">WHITE</td><td rowspan="27">LOCKWOOD</td></tr>
<tr><td>Riesling</td><td>W</td><td>C</td></tr>
<tr><td>Grüner Veltliner</td><td>W</td><td>C</td></tr>
<tr><td>Auxerrois</td><td>W</td><td>C</td></tr>
<tr><td>Petit Manseng</td><td>W</td><td>M</td></tr>
<tr><td>Rkatsitelli</td><td>W</td><td>M</td></tr>
<tr><td>Cabernet Franc</td><td>C</td><td>C</td><td rowspan="8">RED</td></tr>
<tr><td>Lemberger</td><td>C</td><td>C</td></tr>
<tr><td>Gamay</td><td>W</td><td>M</td></tr>
<tr><td>Zweigelt</td><td>C</td><td>C</td></tr>
<tr><td>Merlot</td><td>H</td><td>M</td></tr>
<tr><td>Pinot Noir</td><td>C</td><td>C</td></tr>
<tr><td>Syrah</td><td>W</td><td>M</td></tr>
<tr><td>Cabernet Sauvignon</td><td>H</td><td>M</td></tr>
<tr><td>Cayuga</td><td>C</td><td>C</td><td rowspan="24">HYBRID</td><td rowspan="7">WHITE</td></tr>
<tr><td>Frontenac Gris</td><td>C</td><td>VC</td></tr>
<tr><td>Vidal*</td><td>W</td><td>C</td></tr>
<tr><td>Traminette</td><td>W</td><td>C</td></tr>
<tr><td>NY 81.0315.17*</td><td>C</td><td>C</td></tr>
<tr><td>Skujins 675*</td><td>C</td><td>C</td></tr>
<tr><td>Aromella</td><td>W</td><td>C</td></tr>
<tr><td>Chambourcin*</td><td>W</td><td>C</td><td rowspan="6">RED</td></tr>
<tr><td>Frontenac*</td><td>C</td><td>VC</td></tr>
<tr><td>Marquette*</td><td>C</td><td>VC</td></tr>
<tr><td>MN 1235</td><td>C</td><td>VC</td></tr>
<tr><td>Noiret</td><td>W</td><td>C</td></tr>
<tr><td>Saint Croix*</td><td>C</td><td>VC</td></tr>
<tr><td>Vidal*</td><td>W</td><td>C</td><td rowspan="5">WHITE</td><td rowspan="11">WINDSOR</td></tr>
<tr><td>Brianna</td><td>W</td><td>C</td></tr>
<tr><td>La Crescent</td><td>C</td><td>VC</td></tr>
<tr><td>NY 81.0315.17*</td><td>C</td><td>C</td></tr>
<tr><td>Skujins 675*</td><td>C</td><td>C</td></tr>
<tr><td>Frontenac*</td><td>C</td><td>VC</td><td rowspan="6">RED</td></tr>
<tr><td>Corot Noir</td><td>W</td><td>C</td></tr>
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<tr><td>Chambourcin*</td><td>W</td><td>C</td></tr>
<tr><td>MN 1200</td><td>C</td><td>VC</td></tr>
</table>

Cultivars were classified as to whether they preferred a cool (C), warm (W), or hot (H) growing season (GS), and if they could survive a mild (M), cold (C) or very cold (VC) dormant season (DS). (see Table 1). Our objectives were

1. To match the training and pruning method to the habit of growth for each winegrape cultivar.
2. To evaluate the fruit yield, juice quality, susceptibility to disease, and vegetative vigor for each winegrape cultivar.

PLOT DETAILS

The performance (yield and quality), disease susceptibility and survival of these cultivars have been followed over the past 7 years. The one acre plot at Lockwood Farm (Cheshire fine sandy loam with a 3 to 8 percent slope) is planted to 14 vinifera (European winegrape) cultivars and 13 hybrid cultivars. The 0.3 acre plot at The Valley Laboratory (Windsor loamy sand on the level) is planted to 11 hybrid cultivars of winegrape. Seven hybrid cultivars are, collectively, planted at both sites (see Table 1: asterisks *). Vinifera grapes are more desirable for wine making, but the vines must be grafted on American rootstock, yield less, and are more prone to winter injury and disease. Hybrid cultivars are crosses between two American native grapes (*vitis labrusca* and *vitis riparia*) and the European winegrape (*vitis vinifera*). These plants are more productive and more tolerant of disease and cold weather. Hybrid vines tend to be procumbent, that is the new shoots tend to hang down. On the other hand, vinifera vines tend to grow upright. For this reason, two methods of training were used. The vinifera grapes were trained to the middle wire of the trellis (height of 32 inches) with new shoots growing upwards. This training method is called ***VSP*** or vertical shoot positioning (Figure 1). A main trunk from the vine is allowed to grow to the bottom support wire of the trellis. From here two canes or “cordons” are trained to either side along the wire. A low “T” structure is formed. During the growing season, shoots elongate, form canes and grow from the primary buds. These are trained through wires above the structural support wire to keep the vines upright and tidy. This method gives the appearance of a candelabrum. This design is easy to prune and harvest and best known by growers.

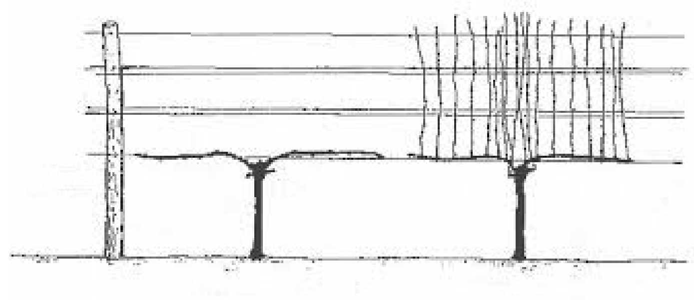

Figure 1. Vertical Shoot Positioning (VSP).

Hybrids, on the other hand, were trained to the top wire (height of 70 inches) with new shoots hanging downwards. This training method is called ***HRU*** or the “Hudson River Umbrella” (Figure 2), and is similar to VSP, but instead of securing the cordon arms to the first support wire, the trunk is taller and the cordons are trained to the top wire. Shoots are allowed to cascade down like an umbrella. This method is good for very vigorous cultivars, but invades slightly into the path between rows. Harvest is easy with this method as the fruit is borne at eye level height.

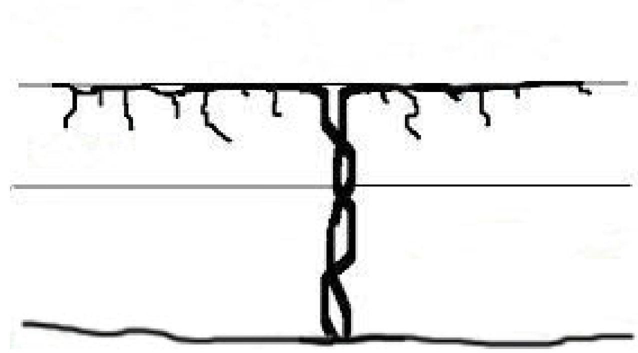

Figure 2. Hudson River Umbrella (HRU).

A grape vine sends off new growth or shoots from nodes which are enlarged areas on the stem where the buds are located. Each node can contain several buds, but generally will have three. Those include:

1. **Primary** bud which is the largest and produces the major grape cluster production,
2. the **Secondary** bud which will produce about 1/3 to ½ of the possible yield of the primary bud only if the primary bud is injured or compromised in some way, and

3. **Tertiary** bud which only produces vegetative growth. The Tertiary bud is still important if winter or mechanical injury has killed the primary and secondary buds. This bud will maintain the growth of the plant allowing stems and leaves, which in turn will produce sugars, to sustain the growth of the vine.

There are dozens of methods for pruning grapes. No one method works for every cultivar of grape. Here in Connecticut we employ several methods. They can be broken down into 2 major categories: *Cane* Pruning and *Spur* Pruning (Figure 3).

Vines can be *cane* or *spur* pruned following several different designs.

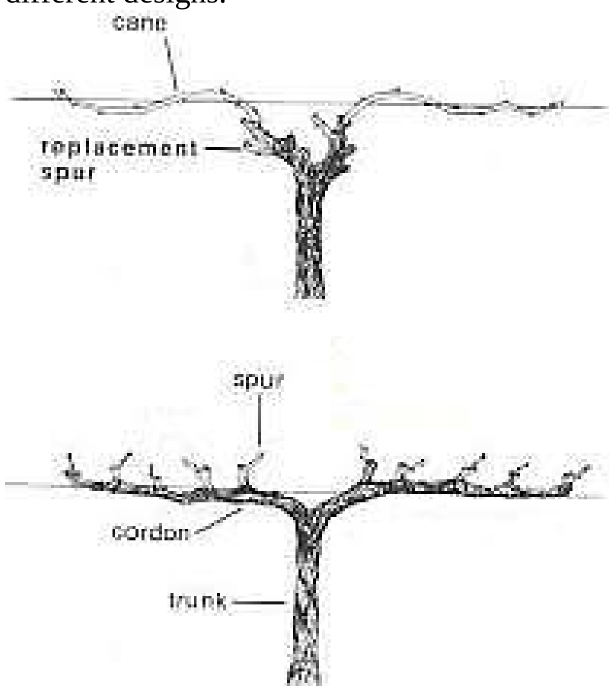

Figure 3. Cane pruning (top) versus Spur pruning (bottom).

When using the ***Cane pruning*** method, a new cane is selected each year. A one year old shoot (growth from the previous year) is selected from as close to the main trunk as possible. The growth beyond that point where the previous cordon was growing along the support wire is cut off and the one year cane is laid down and secured to the wire. This method provides new clean tissue each year. It is a good practice to keep a two bud spur, near this cane and the main trunk, to be used as the lay down cane for next year. By thinking ahead to coming years while pruning you can provide various shoots for renewal selection.

Using the ***Spur pruning*** method the T structure is maintained, but instead of pruning off everything beyond the first shoot, the cordon remains on the guide/support wire and the one year shoot growth is trimmed to several buds. These little stubs are called *spurs*. If the vine has been very vigorous and you wish to reduce the vigor, you can leave more than two buds per spur. If you wish to increase the vigor you should choose two buds. With this method you retain last year's structure/framework. The cordon/arms are kept from year to year and get larger and woodier. This method is faster to prune, but keeps old wood which could harbor more disease problems. Very often, there are multiple shoots coming from a bud. When spur pruning, it is important to maintain the shoots as close to the cordon/arm as possible. Select the spur originating closest to the cordon. If you just shorten last year's growth and don't maintain one shoot per node you will end up with multiple shoots and too dense growth. There should be single shoots about a hand width apart on the cordon (about five nodes per foot of cordon). When selecting spurs to be cut off, think of the design you wish to use. HRU spurs preferably should face down while VSP spurs should face upward, if at all possible. Both cane and spur pruning are trained the same from this point on. The chosen design method is then followed.

At Lockwood Farm, vines were planted six feet apart in 13 north-south oriented rows spaced nine feet apart. Cultivars were arranged in a randomized block design with six blocks consisting of four contiguous vines for each cultivar. At The Valley Laboratory, vines were planted eight feet apart in 6 northeast-southwest oriented rows spaced nine feet apart. Cultivars were arranged in a randomized block design with four blocks consisting of three contiguous vines for each cultivar. Both plots were protected with a bird netting tent suspended above the entire plot at a height of ten feet. Pest management was a standard grape integrated pest management (IPM) program based on the current New York and Pennsylvania Pest Management Guidelines for Grapes (Cornell and Penn State Cooperative Extension). Shoots were thinned to 5 shoots per linear foot of row in all years. Approximately 50% of the leaves in the immediate fruit zone were removed late each July.

FRUIT AND VINE DATA COLLECTED

Fruit yield, number of clusters, dormant cane pruning weights, and the number of retained nodes after pruning were collected on a vine-by-vine basis each year. At the time of harvest, 100 berry random samples were collected and frozen for later fruit quality analysis. The Ravaz index, an indicator of vine balance, was calculated on a vine-by-vine basis by dividing the yield in pounds per vine by the pounds of cane prunings from the following spring's pruning weights (Ravaz 1911). The previously frozen berry samples were thawed to room temperature, crushed by hand, and filtered through cheesecloth and filter paper. Each berry sample was measured individually for °Brix, *p*H, and titratable acidity (expressed as percent tartaric acid equivalents by weight) according to the methods of Iland et al. (2002).

WEATHER SUMMARY

Remote internet-accessed weather stations at the two vineyards monitored air and soil temperature, insolation, relative humidity, precipitation, leaf wetness, soil moisture, wind speed and direction, every 15 minutes.

Rainfall and Growing Degree Days during the growing seasons (April to October, inclusive) were highly variable over the four years of the trials (Fig 4 and 5). For comparison, the 20 year averages (1981-2010) for Rainfall and Growing Degree Days are also shown in Figures 4 and 5, respectively. Note Bradley International Airport is 2.9 miles north of the Windsor planting (dashed blue line) and the Lockwood Farm weather station (dashed red line) is 1500 feet northeast of the grape planting.

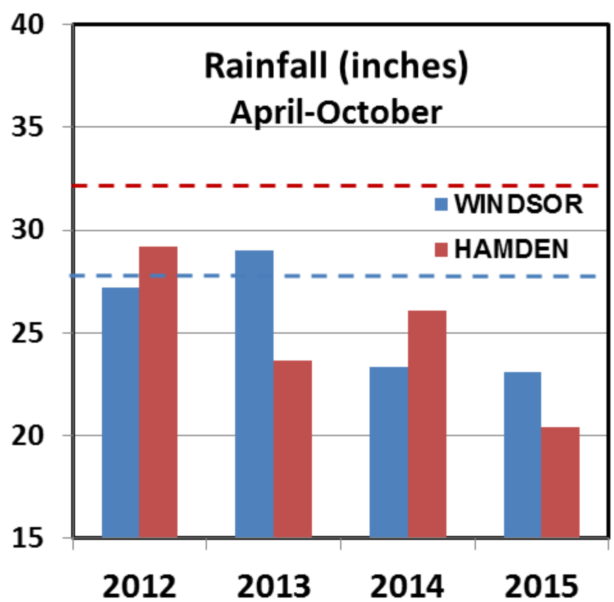

Figure 4. Rainfall at Windsor and Hamden during the growing season for the four years of the study. 20 year averages for Bradley Airport (dashed blue line) and Lockwood Farm (dashed red line) are also shown.

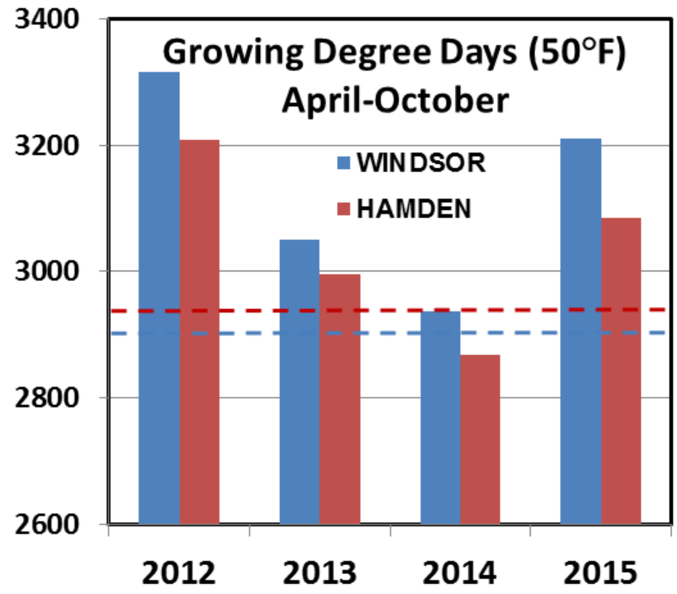

Figure 5. Growing degree days (based on 50°F) at Windsor and Hamden during the growing season for the four years of the study. 20 year averages for Bradley Airport (dashed blue line) and Lockwood Farm (dashed red line) are also shown.

The severity of the preceding dormant season (winter) is very important in determining survival and fruitfulness of winegrapes. The chill duration, defined as the length of time below a certain temperature, for each of the four years is shown

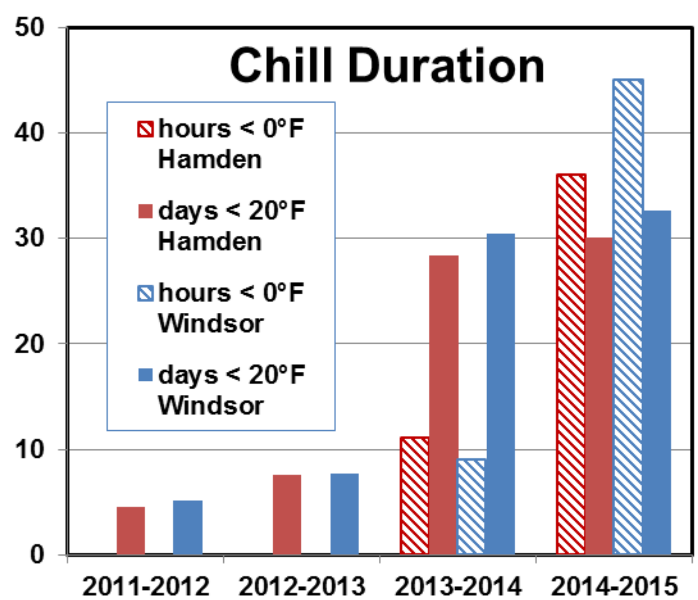

Figure 6. The chill duration, defined as the length of time below 0° F (hours: diagonally hatched bars) and 20° F (days: solid bars), for Hamden (red) and Windsor (blue) over the four winters of this study.

The performance of European wine grapes is particularly affected by the severity of the preceding winter. Under "cold" conditions many primary and secondary buds are killed. For cane pruned vines, this severely restricts the number of clusters that can be produced. For spur pruned vines, the viticulturist has the option to compensate for bud loss by leaving more buds on each spur. Under "very cold conditions" many hybrids can also be affected. Ultimately, yield loss is highly dependent on many factors, including wind speed and snow cover. In summary, the years from 2012 to 2015 exhibited great variation in climactic variables (summarized in Table 2).

Table 2. Summary of climate variation at Hamden CT and Windsor CT (2012 – 2015).

SITE	YEAR	Growing Season	Rainfall	Dormant Season
Hamden	2012	HOT	LOW	NORMAL
	2013	NORMAL	VERY LOW	NORMAL
	2014	NORMAL	VERY LOW	COLD
	2015	HOT	VERY LOW	VERY COLD
Windsor	2012	HOT	NORMAL	NORMAL
	2013	NORMAL	NORMAL	NORMAL
	2014	NORMAL	LOW	COLD
	2015	HOT	LOW	VERY COLD

In general, rainfall over the four year period was farther below the 20 year average at the Hamden location than at the Windsor site (Figure 4). At both locations there were two hotter than average growing seasons (2012 and 2015) and two normal growing seasons (2013 and 2014). Over the four year period, the severity of the dormant season became increasingly severe at both locations (Figure 6).

RESULTS

Damage due to disease and winter injury.

Yield from the 2012 season was not affected by foliar disease, fruit rots or winter injury. The 2013 fruit harvest, however, was marred by a high incidence of fruit rots. This was partially due to the frequent rains in September during the mid-season harvest. However, the problem was particularly severe for the rows where bird netting was tacked over the vines and secured to the ground. This reduced the effectiveness of fungicide sprays and reduced air circulation. Fruit rots were particularly a problem for tight clustered grapes such as Pinot Blanc, Pinot noir, Auxerois and Aromella.

In 2014, cold weather in January caused extreme winter injury. On 4-5 January 2014 temperatures remained below 0°F (-17.8°C) for 8 hours reaching a minimum of -5.8°F (-21°C) in Hamden and -3.8°F (-19.9°C) in Windsor (Figure 6). This resulted in 20-40% bud kill on vinifera varieties whether cane or spur pruned. April was colder than usual and bud break was about 2 weeks late for all cultivars (10 May – 25 May). Flowering was also 2 weeks late (8 June – 25 June). Heavy rains during the last week of May and the first week of June resulted in an outbreak of Downy Mildew in the Hamden plot (first observed 18 June). Prompt fungicide application prevented any infection to fruit. However, the vinifera cultivars suffered between 20% - 45% foliar damage. Powdery mildew was not a major problem in Hamden, CT, however, yield of vinifera (not included in this study) in Windsor, CT were devastated by this disease, although Downy Mildew was not a problem. The phenology caught up during the summer and veraison was just 5-7 days later than usual (6 August – 21 August).

This pattern of bud kill was repeated during the 2014-2015 winter (Figure 5). On four occasions in February of 2015 (February 14th, 16 th, 21st, and 24 th), temperatures remained below 0°F (-17.8°C) for at least 7 hours, reaching minimum values ranging from -3 to -8°F in Hamden and from -6.3 to -7.7°F in Windsor (Figure 6). During this 11 day period (February 14 – 24, 2015), temperatures never rose above freezing (32°F). This resulted in 40-60% bud kill on vinifera varieties and 20-40% bud kill on the more sensitive hybrids (Chambourcin, Corot Noir, Noiret, Briana, and Aromella). The spring and summer of 2015 were hotter than average and the phenology of the plants (bud break during the first week of May and flowering during the first two weeks of June) proceeded normally. In 2015, due to the hot dry conditions, veraison (the onset of ripening) and harvest were between 7 and 10 days ahead of schedule and foliar diseases and fruit rots were not a major problem.

Summary of fruit yield.

Due to the extreme variation in climate and the coincident large variation in yield from year to year, the four year (2012-2015) averages of all pertinent quantities are presented in Table 3.

Table 3. Vegetative and fruit quality parameters for two Connecticut vineyards averaged over four years (2012-2015). [* indicates cultivar is planted at both sites].

SITE	TYPE	COLOR	Cultivar	Berry Wt. lb/100	°Brix	pH	TA %	Harvest DOY	Harvest date	Yield lb/vine	Number of Clusters	Ravaz[1] Index
Hamden CT	VINIFERA	WHITE	Pinot Blanc	0.57	19.3	3.94	0.57	271	28-Sep	9.00	85	5.5
			Riesling	0.39	18.3	3.70	0.59	292	19-Oct	8.93	51	3.9
			Grüner Veltliner	0.46	20.0	4.19	0.43	289	15-Oct	8.16	47	6.7
			Auxerrois	0.46	19.5	4.07	0.45	276	2-Oct	7.77	83	6.6
			Petit Manseng	0.26	24.0	3.55	0.87	295	22-Oct	7.39	79	4.2
			Rkatsitelli	0.57	18.9	3.84	0.65	284	11-Oct	4.91	30	1.9
		RED	Cabernet Franc	0.39	19.9	3.92	0.54	282	8-Oct	8.73	70	4.1
			Lemberger	0.40	19.5	3.82	0.70	289	16-Oct	8.45	39	3.4
			Gamay	0.47	19.2	3.77	0.60	284	10-Oct	7.79	53	8.2
			Zweigelt	0.48	18.8	3.84	0.54	275	2-Oct	7.50	49	6.1
			Merlot	0.40	20.1	3.88	0.50	299	25-Oct	6.71	30	2.7
			Pinot Noir	0.36	19.5	4.00	0.67	270	27-Sep	6.16	75	3.9
			Syrah	0.44	19.1	3.89	0.66	297	24-Oct	5.26	32	3.3
			Cab Sauvignon	0.28	20.3	3.94	0.71	297	23-Oct	3.15	28	3.4
	HYBRID	WHITE	Cayuga	0.63	19.5	3.62	0.50	280	6-Oct	26.49	124	47.8
			Frontenac Gris	0.27	23.9	3.55	1.15	270	27-Sep	25.45	107	11.0
			Vidal*	0.42	19.5	3.72	0.67	293	20-Oct	22.84	87	35.8
			Traminette	0.40	20.1	3.74	0.62	281	8-Oct	20.46	86	10.8
			NY 81.0315.17*	0.41	21.4	3.83	0.57	282	8-Oct	14.74	124	15.8
			Skujins 675	0.33	20.2	3.81	0.53	276	3-Oct	14.37	125	29.8
			Aromella	0.40	17.9	3.61	0.81	290	16-Oct	12.01	84	13.0
		RED	Chambourcin*	0.52	18.6	3.52	0.77	290	16-Oct	27.19	103	40.1
			Frontenac*	0.25	22.1	3.56	1.18	272	29-Sep	22.09	119	8.5
			Marquette*	0.33	23.1	3.82	0.84	274	1-Oct	17.47	121	15.4
			MN 1235	0.29	20.7	3.76	0.80	276	2-Oct	16.46	126	13.4
			Noiret	0.43	18.8	3.76	0.61	290	16-Oct	12.67	65	4.3
			Saint Croix*	0.40	19.0	4.06	0.57	267	23-Sep	11.66	128	8.6
Windsor CT	HYBRID	WHITE	Vidal*	0.43	21.4	3.47	0.60	286	13-Oct	24.18	121	29.9
			Brianna	0.57	22.2	3.79	0.47	256	12-Sep	19.51	106	21.5
			La Crescent	0.29	24.2	3.41	0.85	258	15-Sep	18.35	131	23.1
			NY 81.0315.17*	0.35	21.5	3.50	0.56	267	23-Sep	15.14	131	11.7
			Skujins 675	0.29	19.9	3.43	0.68	257	13-Sep	12.08	115	24.6
		RED	Frontenac*	0.26	25.0	3.33	1.07	267	24-Sep	26.58	153	16.3
			Corot Noir	0.55	19.6	3.58	0.45	284	10-Oct	22.57	107	20.8
			Marquette*	0.32	25.3	3.55	0.72	255	11-Sep	17.64	159	8.1
			Saint Croix*	0.39	20.7	3.73	0.55	255	11-Sep	16.04	152	10.6
			Chambourcin*	0.49	22.2	3.33	0.70	286	12-Oct	13.18	100	17.2
			MN 1200	0.19	22.3	3.50	0.65	257	14-Sep	9.75	116	12.2

[1] The Ravaz index, an indicator of vine balance, was calculated on a vine-by-vine basis by dividing the yield in pounds per vine by the pounds of cane prunings from the following spring's pruning weights (Ravaz 1911).

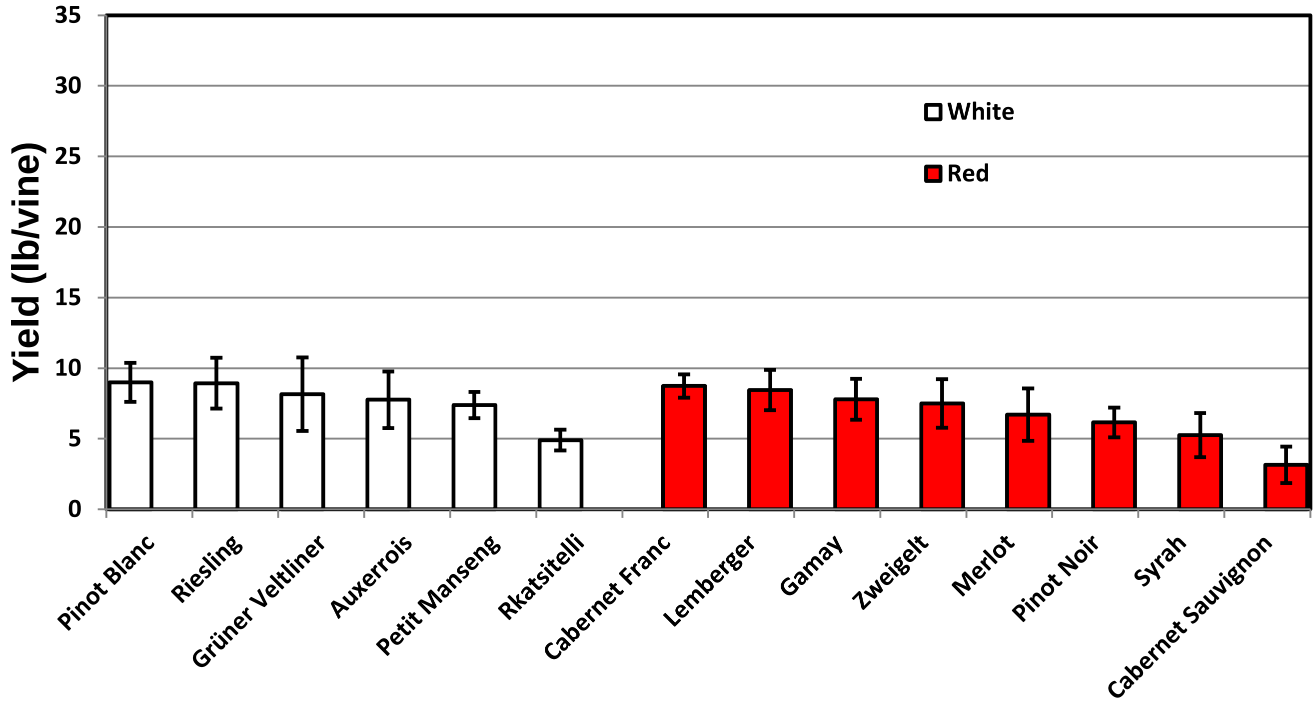

Figure 7. Grape yield averaged over 4 years (2012-2015) for European winegrapes at Lockwood Farm (Hamden CT). Error bars represent the 95% probability range for yield.

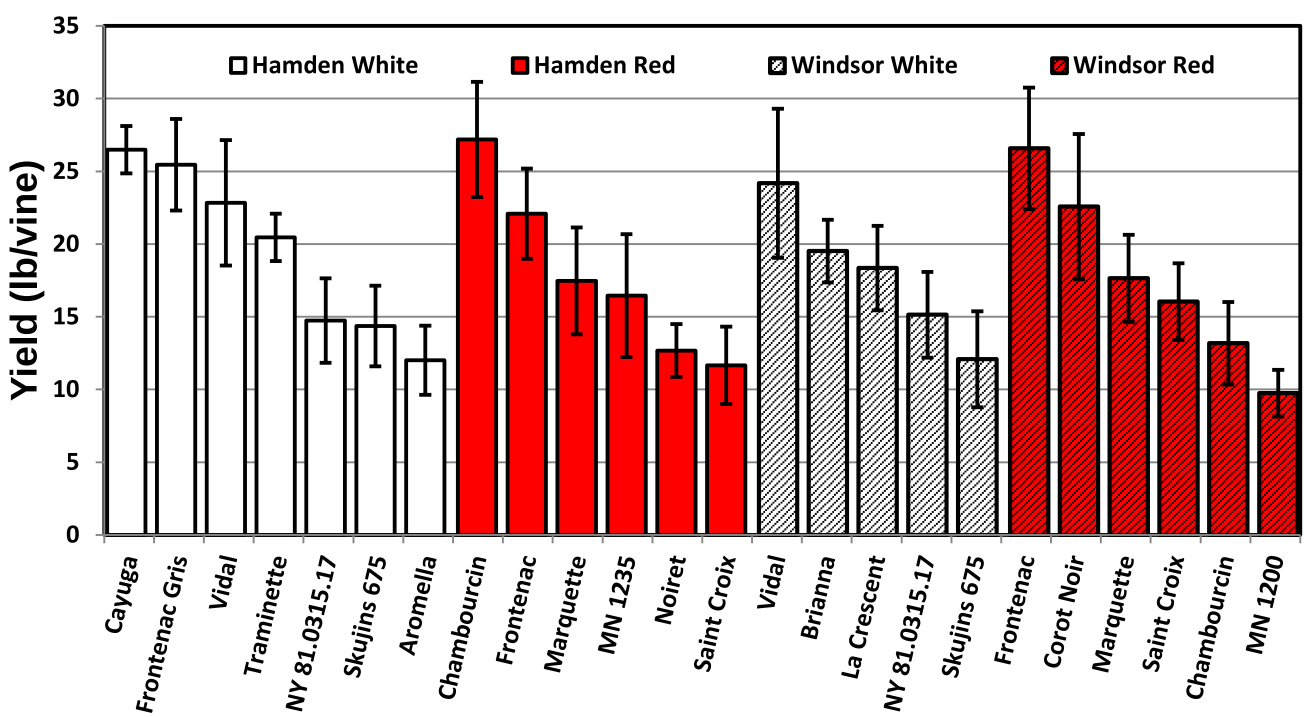

Figure 8. Grape yield per vine averaged over 4 years (2012-2015) for hybrid winegrapes at Lockwood Farm (Hamden CT) and The Valley Laboratory (Windsor CT). Error bars represent the 95% probability range for yield.

Average fruit yield in pounds per plant are plotted in Fig 6 and 7 for vinifera and hybrids, respectively. It is hoped that this collective result may represent how these various cultivars might perform over the much longer expected life of a vineyard (15-30 years). In general, vinifera vines produced about half the fruit yield of hybrid cultivars (Fig 7 and 8). However, these grapes are more valued and, in some years, may bring twice the price per pound. Thus, from an economic standpoint, yields were comparable.

Damage due to disease and insects.

Another factor affecting yield and quality of fruit is the response of the various cultivars to pathogens and insects. Major disease problems in Connecticut are fruit and foliar damage due to Powdery Mildew (caused by *Erysiphe necator*) and Downy Mildew (caused by *Plasmopara viticola*) and late season fruit rots (anthracnose, bitter rot, black rot, Botrytis bunch rot, ripe rot, and sour rot). The damage due to these pathogens was estimated over the four years of this study and the result is summarized in Table 4.

The only major insect problem is caused by foliar Phylloxera [*Daktulosphaira vitifoliae* (Fitch)]. This insect deposits its eggs into leaves resulting in deforming galls. In severe infestations, the deformation of affected leaves can greatly reduce photosynthesis, thereby reducing yield, fruit sugar content, and vegetative vigor. These insects preferentially attack riparian hybrids, which are the most cold-hardy winegrapes (see Table 4).

Vine Mortality.

Over the course of this study, a considerable number of the vines planted in 2008 have died. Some vines succumbed to Crown Gall [*Agrobacterium vitis* (Ophel & Kerr 1990)] after two or three years. This bacterial infection in the trunk of the grape vine causes a swollen woody gall that restricts the flow of nutrients upwards and the flow of sugar down to the roots. When this gall girdles the trunk, all tissue above this point dies. Sometimes the vine may sprout below the infection and survive for a year or two. However, eventually the infection spreads and the entire vine dies. In this study, the cultivars most affected by this problem were Syrah, Zweigelt, Cabernet Sauvignon, Lemberger, and Petit Manseng (Table 4). Note that these are all vinifera cultivars and are not very cold hardy (Table 1). The onset of Crown Gall is thought to be associated with wounds in the trunk caused by frequent freeze-thaw cycles, which can result in cracks in the trunk of the grapevine. In Connecticut, January and early February are characterized by large temperature variation. In years when there is no snow cover to insulate the trunk, repeated episodes of freezing and thawing during this period often cause cracks in the trunk of grapevines. This allows the bacteria to enter and results in this devastating disease.

Another problem that can result in mortality is caused by viruses. Our planting of the vinifera cultivar Merlot was severely affected by Grapevine red blotch-associated virus (GRBaV). This virus first stunts the plant, then leaves turn prematurely red, and eventually the plant dies. A Merlot plant exhibiting the classic symptoms of this disease is shown in Figure 9 (picture taken June 2010). This vine died the following year (2011). Over the course of this study 54% of the Merlot vines succumbed to this disease (Table 4). The virus can be spread by sucking insects and on pruning shears. For this reason affected plants were always pruned last to avoid the spread of this virus.

Figure 9. Merlot vine planted at Lockwood Farm (Hamden CT) in 2008 infected with Grapevine red blotch-associated virus (GRBaV). Picture was taken June 18, 2010.

Table 4. Estimates of observed damage due to fruit rots (FR), Powdery Mildew (PM), Downy Mildew (DM), Phylloxera (PH), and winter bud kill. (*** severely affected, ** moderately affected, * slightly affected). Mortality is the percentage of vines that died due to winter injury, crown gall or virus infection over the 7 years since planting in 2008.

SITE	TYPE	COLOR	CULTIVAR	FR	PM	DM	PH	Bud kill	Mortality %
Hamden CT	VINIFERA	WHITE	Auxerrois		**	**		*	0
			Grüner Veltliner	**	*	**		**	0
			Petit Manseng			**		*	21
			Pinot Blanc		***	***			8
			Riesling	*	**	**			0
			Rkatsitelli		*	*			0
		RED	Cabernet Franc		**	**		*	0
			Cabernet Sauvignon		**	***		***	46
			Gamay	*	**	***		*	4
			Lemberger		*	**		*	17
			Merlot	*		***		***	46
			Pinot Noir	*	***	***		**	4
			Syrah		***	***		***	75
			Zweigelt	*	*	**		*	33
	HYBRID	WHITE	Aromella	***		*	*	**	4
			Cayuga			*		*	13
			Frontenac Gris	***		*	***		21
			NY 81.0315.17	**			*		8
			Skujins 675	**					8
			Traminette	***		*	**		0
			Vidal				*		0
		RED	Chambourcin			*	*	*	0
			Frontenac			*	***		0
			Marquette	**		*	*		4
			MN 1235			*	*		4
			Noiret					**	4
			St. Croix	*	*	**	**	**	0
Windsor CT	HYBRID	WHITE	Brianna			*		**	6
			LaCrescent			*	**		0
			NY 81.0315.17				*	**	0
			Skujins 675				*		0
			Vidal				*		0
		RED	Chambourcin	**		*	*	***	0
			Corot Noir					**	0
			Frontenac				***		0
			Marquette				**		6
			MN 1200				*		0
			St. Croix	*	*	**	***	**	0

DISCUSSION

Pruning a grape vine stimulates vegetative growth. When too many fruiting buds are left on the plant, many grape clusters are formed. As the plant grows, less sugar is available to make new vegetative shoots. The result is inferior fruit and a weakened plant, since there is not enough leaves to photosynthesize and feed all. Ideally, the goal is to keep the vine in balance so that a limited number fruit is produced, balanced by enough vegetative growth to fill the fruit with sugar and maintain the plant. The Ravaz index, an indicator of vine balance, is calculated by dividing the yield in pounds per vine by the pounds of cane prunings from the following spring's pruning weights (Ravaz 1911, Table 3). Large values of this index indicate that the vines have been over-cropped. This is usually the result of leaving too many fruiting buds when pruning or fertilizing too heavily. On the other hand, a low value of the index indicates over pruning or severe bud-kill during the dormant season. The range of acceptable values for the Ravaz index is quite large. Kurtural (2007) states the optimum to be between 5 and 14, although Reynolds (2000) indicates that 12 is the maximum for optimum wine quality. In general the acceptable value of the Ravaz is higher for hybrids. In this trial, many vinifera cultivars tended to have low (<5) values for the Ravaz index (Table 3). The major cause was winter damage to fruiting buds. This can be somewhat compensated for by leaving more buds on the plant when pruning in if the winter has been severe. The vinifera cultivars Pinot Blanc, Grüner Veltliner, Auxerois, Gamay, and Zweigelt were least affected and appeared to maintain a proper balance between vegetative growth and fruiting. On the other hand, a number of the hybrid cultivars had very large values for the Ravaz index (Cayuga, Vidal, Skujins 675, and Chambourcin in Hamden). This indicates that these cultivars were over-cropped and should be pruned back more severely in the future. This might reduce overall yield but fruit sugar content and quality would improve.

Mortality (Table 4) due to viruses and winter damage was high for the more heat loving vinifera (Merlot, Cabernet Sauvignon and Syrah). In Connecticut, these cultivars should only be planted near to the coast, where winters are less severe. In general, the vinifera cultivars which survive well and had acceptable production were Pinot Blanc, Auxerois, Riesling, and Grüner Veltliner for the whites and Cabernet Franc, Gamay Noir and Pinot Noir for the reds.

Production for all hybrids was always above 10 pounds per plant, which is equivalent to 4 tons per acre. Mortality was a concern for Cayuga White and Frontenac Gris (Table 4). However, these are very high yielders (Figure 8) and replanting 4-6% each year is worth considering. The cultivar Chambourcin performed very differently at the two locations. At Hamden, it consistently had the highest yields of all the red hybrids. At Windsor, however, the vines were weak and production was low. This may be due to the difference in soil type. The soil at Windsor is very sandy and well drained. The last two years of this study (2014 and 2015) were characterized by low rainfall. The soil at Hamden has a much larger clay and organic component, which retains moisture.

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