THE POTENTIAL OF *VITIS VINIFERA* PEST MANAGEMENT IN WASHINGTON

by

Geoffrey W. Menzies

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Name: Geoffrey Menzies

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Examining Committee

Chairman: Dr. M. Mackauer

Dr. H. R. MacCarthy, Senior Supervisor

Dr. James E. Rahe

Dr. F. D. McElroy, Nematologist & Owner, private pest management consulting service, Public Examiner

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Author: ______________________
(signature)

____
(name)

Jan 25, 1984
(date)

ABSTRACT

The potential for pest management in growing wine grapes in central Washington is examined here, based on communication with professionals in government and the industry, on a survey of literature, and on the responses of 32 growers to a questionnaire. The industry is appropriate for integrated pest management (IPM) because of the following factors: vineyard pests are more easily reduced and suppressed by natural means than are pests in annual crops; pest control costs are high, averaging about $145/acre; wine grapes are a high value crop; recent expansion in terms of acreage planted has been explosive; future growth is hardly limited by available suitable land; the present and anticipated acreage is still within a relatively compact area; the current level of competition between growers demands that inputs are optimized; and successful IPM is already practiced in California.

Most of the growers surveyed responded positively to the suggested outline of a pest management service and favored the idea of advice from a fully independent consultant hired on the basis of acreage.

The habits and current status of pests of wine grapes and the control options available are discussed, as well as the services that could be provided by a pest manager. Limited local research up to now means that action thresholds and sampling methods have been established for a few pests only, and some key environmental factors have yet to be identified.

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European wine grapes, *Vitis vinifera L.*, were first planted in eastern Washington around 1900 when this semi-desert region was first beginning to come under irrigation (Anon. 1982). However, expansion of the wine industry in Washington was very slow until about the last 15 years. In 1967, Andre Tchelistcheff sampled a Gewurztraminer from the Yakima Valley and pronounced it the best Gewurztraminer yet produced in the United States (Meredith 1980). At approximately the same time, intensive viticultural research was started by Washington State University (W.S.U.). This early research concentrated on identifying the most suitable vineyard sites and varieties. The ultimate test, of course, was the judgement of the wine quality associated with variety and site. These studies, in addition to a growing acceptance of varietal wines produced in Washington, helped to set off an explosion in this industry within the past five years. There are at present (1983) 7906 acres [1] of European varietal grapes planted in the state, of which 4502 acres have been planted since 1980 and have not yet come into production (Folwell, Kirpes, and Nagel 1983). By the end of 1983, about 1500 acres will have come into production for the first time,

[1] Since this paper is written largely for reading within the United States, where metric units of measurement have not been adopted, the English system has been retained.

increasing the state's previous total production by almost 50%. This rapid growth in acreage planted is not the only form of growth that this industry has undergone.

About ten years ago, there were four wineries in the state. Now there are more than 30 bonded wineries and apparently more in the planning stages (Anon. 1982). The industry is dominated by one winery, Chateau Ste. Michelle, which owns and manages 2800 acres of vines, 50% of which are now bearing. At the opposite end of the size scale is the Hinzerling winery of the lower Yakima Valley, which produces wines from its own 24 acres of vines. Both wineries purchase grapes from independent growers to supplement their own crops.

Compared with other crops grown in the irrigated farm land of eastern Washington, wine grapes can yield high monetary returns, dependent on several factors. Among these are the variety grown, yield, local winery supply and demand, and the international marketplace. The average revenue is at present $3615/acre from an average yield of 5.44 tons/acre (Kirpes & Folwell 1983). These figures are the means of the eight leading varieties grown. The estimated total production costs for a mature 50-acre vineyard made up of equal amounts of these eight varieties, is $2161/acre (Kirpes & Folwell 1983). By simply subtracting total production cost from average revenue, the average net return to management is $1453/acre.

The costs of vineyard establishment are also high relative to other agricultural crops. Excluding the price of land, the establishment costs over the first three years are $7068/acre. A small crop is harvested at the end of the third season worth about $1352/acre which reduces the net investment to $5716/acre for a three-year-old vineyard (Kirpes and Folwell 1983). This still represents a substantial investment, particularly as vineyard size increases. For example, the net investment on a three-year-old, 50-acre vineyard is about $285,000.

Total pest control costs on mature vineyards are estimated at $145/acre, representing 6% to 7% of the annual total production costs (Kirpes & Folwell 1983). Losses to certain pests can be substantial, particularly to the uninformed producer who may have had little previous experience in viticulture. Due to the recent surge of growth in this industry, there has been little time for agricultural research in wine grape production. Research on grapes in Washington has concentrated primarily on the cv. Concord, derived from the wild fox grape, which has long dominated grape production. Until now, most of the wine grape research conducted in Washington has addressed the important basic issues of site selection and varietal adaptation. Little work has been directed toward cultural practices and even less to pest management, which is too new to be sophisticated, but should improve with increased local research and experience.

This study is an effort to give an overview of the known pest problems facing the wine grape industry in the state, and to determine the potential for improved, more knowledgeable pest management, primarily through an independently operated pest management consultant service. There are several reasons for considering the potential of professional pest management in this crop at this time.

The relatively high value of wine grapes allows the producer to consider intensive pest management, particularly with a net return to management averaging $1500/acre. The high initial capital investment in vineyard establishment as well as the current economics of the industry, characterized by an apparent imbalance between supply and demand, should make the goal of optimizing production efficiency a top priority. The relatively young association between producers and this crop should result in an open-mindedness to available expertise that may not be so evident in other crops, where the relationship has had a longer time to mature. The industry is clearly in a growth phase at present and future expansion is not limited by available suitable land. From a biological viewpoint, perennial grapevines, like tree fruits, remain relatively undisturbed and able to support a diverse and balanced insect population. This fits well with the pest management concept that attempts to maximize the effects of naturally occurring parasites and predators of key pest species.

To supplement my review of the appropriate literature, a questionnaire was distributed to 32 growers. This survey sampled about 33% of the growers, but represents 82% of the present bearing acreage, 50% of the present non-bearing acreage, and 65%

of the total acreage planted to wine grapes in the state. The greatest value and point of the survey was to measure attitudes of growers toward possible adoption of a pest management service and to gain some insight on pest species being encountered and pest control practices. The majcrity of growers surveyed seemed genuinely interested in improving this aspect of production and some thought that there was a lack of local expertise in wine grape pest management.

II. Production

Viticultural Background

The Washington grape acreage is dominated by Concord grapes, with approximately 20,000 acres planted in this variety in eastern Washington (Folwell, Nagel, and Kirpes 1982). Concord was first cultivated in Concord, Massachusetts in 1852 and is believed to be a cross between the wild fox-grape, V. labrusca, and the Catawba, which is most probably native to North Carolina and was the principal cultivated American wine grape in the 1850's (Wagner 1963). The Concord was an instant success as a table grape, for its fruit was tasty and attractive, and the vine was hardy and would tolerate neglect. However, its strongly "foxy" [1] aroma typical of the grapes native to the eastern United States makes it unsuitable for quality wine production (Wagner 1963).

Over half of the Vitis species in the world are native to North America and there are some major differences between our native species and the European V. vinifera, which is the major wine grape species grown in California, Oregon, Washington and most of the rest of the world. The native American grapes,

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[1] This term refers to the taste imparted by methyl anthranilate, an aromatic substance which develops during the ripening of labrusca-type grapes.

V. labrusca L., V. riparia Michaux, and V. rupestris Scheele, to name a few, have a different root and vine structure, which makes them winter hardy and disease and pest resistant by comparison with V. vinifera. The fruit quality differs also. In general, the fruit of the native species contains much more acid and much less sugar than that of the European vines and is different in appearance, flavor, taste, and smell. Because of the poor quality wine produced from these grapes, there were several efforts to cultivate vinifera in various parts of the eastern U.S., starting as early as 1616. In that year, a vinifera viticulture was attempted in Virginia, but it failed due to some unknown sickness affecting the vines. Over the next two centuries, vinifera vineyards were planted in Massachusetts, Rhode Island, the Carolinas and Georgia, but all the attempts consistently failed. It was not understood at the time why wild grapes should be so prolific when it was so difficult to grow vinifera. The reason was that vinifera lacked natural immunity or resistance to pests and diseases which the wild native grapes had evolved with and could tolerate (Wagner 1963).

In the late 18th century, a vinifera planting in Kentucky was unthrifty with the exception of one variety, a black grape, which appeared to be thriving. This grape, the Alexander, thought to have been planted as seed from the Cape of Good Hope was considered the first vinifera variety to produce well in America. In reality, the Alexander is a cross between native labrusca and introduced vinifera. (Wagner 1963).

After the successful cultivation of the Alexander, American viticulture turned again to cultivation of the native grapes. The Catawba was the principal cultivated native American wine grape, and its origin, like that of the Alexander, is cloudy. More importantly, the wine produced from it was acceptable. Cultivation of native grapes had become a profitable industry by the mid-1800s. Another variety grown was the Clinton, a V.riparia variety which would become the parent of many red wine hybrids to come. With the success of Concord cultivation, grape growers came to realize the value of crossing different varieties and cultivating the offspring. This idea was well advertised and led to the development of several new hybrids in the late 1800s. Most were undesirable, but some became important native wine grapes (Wagner 1963).

It was in the late 1800s that the grape phylloxera, Dactylasphaera (Phylloxera) vitifoliae (Fitch), a root aphid, was ravaging the vineyards of France as an introduced pest. French viticulturists brought native American wine grape varieties to France hoping to use them for direct production, taking advantage of their known resistance to this pest. These varieties were effectively established, but the "foxy" aroma typical of the grapes was not desirable, and tainted the final product. But once grafting techniques were developed, preferred vinifera varieties were grafted onto American rootstocks, thus eliminating the problem of flavor, while using the rootstock's resistance to phylloxera. (Wagner 1963).

The wine grape industry in the eastern U.S. came to be built upon several hybrids which retained resistance to pests and diseases and had improved fruit quality. However, wine produced from these hybrids is still considered inferior to wine produced from pure vinifera grapes, and the area has yet to have any substantial plantings of vinifera. Climate is the biggest factor limiting vinifera production in the region since vinifera are not cold hardy and cannot tolerate the winters.

Though they could not find a home in the eastern states, viniferas are well suited to the Mediterranean climate of California, and by the end of the 19th century, this state was producing 85% of all grapes grown in the U.S., with a corner on the domestic premium wine market (Wagner 1963).

Although the first grape plantings in Washington in 1872 were eastern U.S. varieties planted in the Puget Sound area (Purser 1977), the recent expansion in the grape industry is with vinifera and is in the central part of the state, east of the Cascade Mountains. At present, phylloxera, which has devastated vinifera plantings in both California and Europe, is not considered a problem. The industry would be greatly threatened if it did become established, because all the vines are on their own roots, which have no resistance to the pest.

Geography and Climate

Most of the vinifera grapes produced in Washington are grown east of the Cascade Mountains on irrigated farm lands of the Yakima River Valley between Yakima and the Columbia Basin (Fig.1) Within the Yakima Valley, the heaviest concentration of growers is from Sunnyside to Prosser (Fig.2). In the Columbia Basin, growers are distributed throughout the Tri-Cities area, the district around Richland,Kennewick, and Pasco. A fringe area which is well suited to European grape production is the Wahluke Slope in southern Grant county bordered on the west and south by the Columbia River. This area is being developed for grape production because of its unique climatic characteristics. It offers approximately 4000 heat units in the growing season, (accumulated daily average degrees F over 50), which allows the producer extra freedom in choosing the variety grown. This area is well suited for late maturing varieties. Another fringe area is in the Columbia Gorge. This is along the Columbia River on the Washington-Oregon border where the wet coastal climate, characterized by a 60 in. annual rainfall, quickly transforms to the semi-arid interior climate with a 10 in. annual rainfall, over a mere 30 miles. This area, from Bingen to Goldendale, is unirrigated and although some fine wines are produced, the choice of variety is limited because it receives fewer heat units than do the Yakima Valley, Columbia Basin, and Wahluke Slope. Because of the uniform climate in the Yakima Valley, Columbia Basin, and Wahluke slope relative to the rest of Washington state, and the fact that the vast majority of wine grapes are grown in these regions, I shall limit my discussion of climate to these areas.

Vinifera grapes are commonly grown at elevations ranging from about 400' up to 1200' above sea level. In California, grapes are grown from 200' below sea level to 4000' above, though most vineyards are in a fairly narrow range of elevation (Winkler 1962).

Soil type varies between sites, but in general the soils of central Washington were formed from silty, wind deposited material and weathered basalt bedrock. In some cases, such as the uplands of the Horse Heaven Hills and the Rattlesnake Hills (Fig. 1), the parent material contains a small amount of volcanic ash (Anon. 1981). Soil types range from fine sandy loams to coarse silt loams (Ahmedullah 1980). These soil types may prove to be a great advantage to this viticultural region, since they are thought to deter the successful establishment of the grape phylloxera.

The wine grape region is between 46N and 48N latitude, which corresponds closely to the Bordeaux and Burgundy regions of France. In these northern latitudes, the summer days are long and warm but the nights are cool, conditions which help to produce grapes of excellent sugar-acid balance, and correspondingly high quality wine. Grapes are native to the warm temperate zone between latitudes 34N and 49S, and their culture is most successful there (Winkler 1962). It is interesting that some of the areas from which the highest quality wines are produced such as Bordeaux, Burgundy, and the Rhine and Moselle valleys are in northerly, even borderline, latitudes. This is also true for Washington.

Climate is the most important consideration when evaluating a wine growing region, and local variations in climate will determine viticultural practices, varietal selection, and ultimately the quality of the product (Winkler 1962). The climate of central Washington favors the European grape, which requires long warm dry summers and cool winters (Winkler 1962). Precipitation averages 7-10"/year, most of this occurring during the winter months, making irrigation a necessity. Precipitation is light in summer, increases in the fall, peaks in the winter, and gradually decreases in the spring, with an increase in May and June followed by a sharp drop by early July (Phillips 1970). The low rainfall during the summer is advantageous in vinifera production because it limits problems such as poor berry set, certain fungal diseases, and particularly, late season fruit rots (Winkler 1962).

Growing degree days, or heat units, are used to estimate the rate of growth and development of crops. This is probably the single most useful measurement to determine viticultural suitability (Meredith 1980). If the heat units are too few, the crop will not mature properly, resulting in an acid, poor quality wine. The number of heat units varies considerably depending on the site, slope, aspect, and soil type. Heat units are defined as the difference between the mean temperature for the day and the base temperature, which is 50F for wine grapes. The total heat unit figure for an area is determined by adding the daily heat unit measurements throughout the growing season or by using the monthly averages. The growing season is from about mid-April through mid-or late October. The mean length of the growing season at Prosser is 154 days with a mean annual heat accumulation of 2500 heat units (Phillips 1970). In the upper Yakima Valley near Yakima itself, the heat unit measurement is approximately 2300 (Donaldson 1979). In the lower Yakima Valley and Columbia Basin areas, heat units average 3200; and on the Wahluke Slope, 4000 heat units are the norm (Phillips 1970). Heat units in the Bingen area of the Columbia gorge at Mont Elise Vineyard range from 2000 to 2100 (Meredith 1980). This low accumulated heat restricts the number of suitable grape varieties. Mont Elise Vineyard produces Pinot Noir and Gewurztraminer since these premium varieties are best suited to the micro-climate (Meredith 1980). Most of the acreage in the state receives about 2500 heat units per season. Of the five climatic regions which are used to classify production areas in California (Winkler 1962), all are represented in Washington.

During the warmest months, temperatures in the lower valleys range from the high 80s into the 90s and reach 100F or higher at times, with a daily range of about 35 degrees. An average winter does not threaten vinifera vines if they are properly managed, but occasionally winter damage does occur. In a few of the coldest winters, minimum temperatures have dropped to 0F for 10 to 20 nights and to minus 20F on 3 to 5 nights (Phillips 1970). On the average, frost penetration is 10 to 20 inches. If there is good snow cover, penetration may be reduced to the top few inches. If there is no snow cover preceding extremely cold weather, frost penetration may be 20 to 30 inches (Phillips 1970). It is in this situation, such as occurred in 1978-'79, that growers are liable to suffer vine damage, particularly if protective measures are not taken. "Survival from subzero temperatures is the single most serious problem which confronts growers in this area" (Clore 1982).

Wind is a major erosive force in this part of Washington. During spring and fall, rapidly moving weather systems result in considerable blowing dust (Phillips 1970).

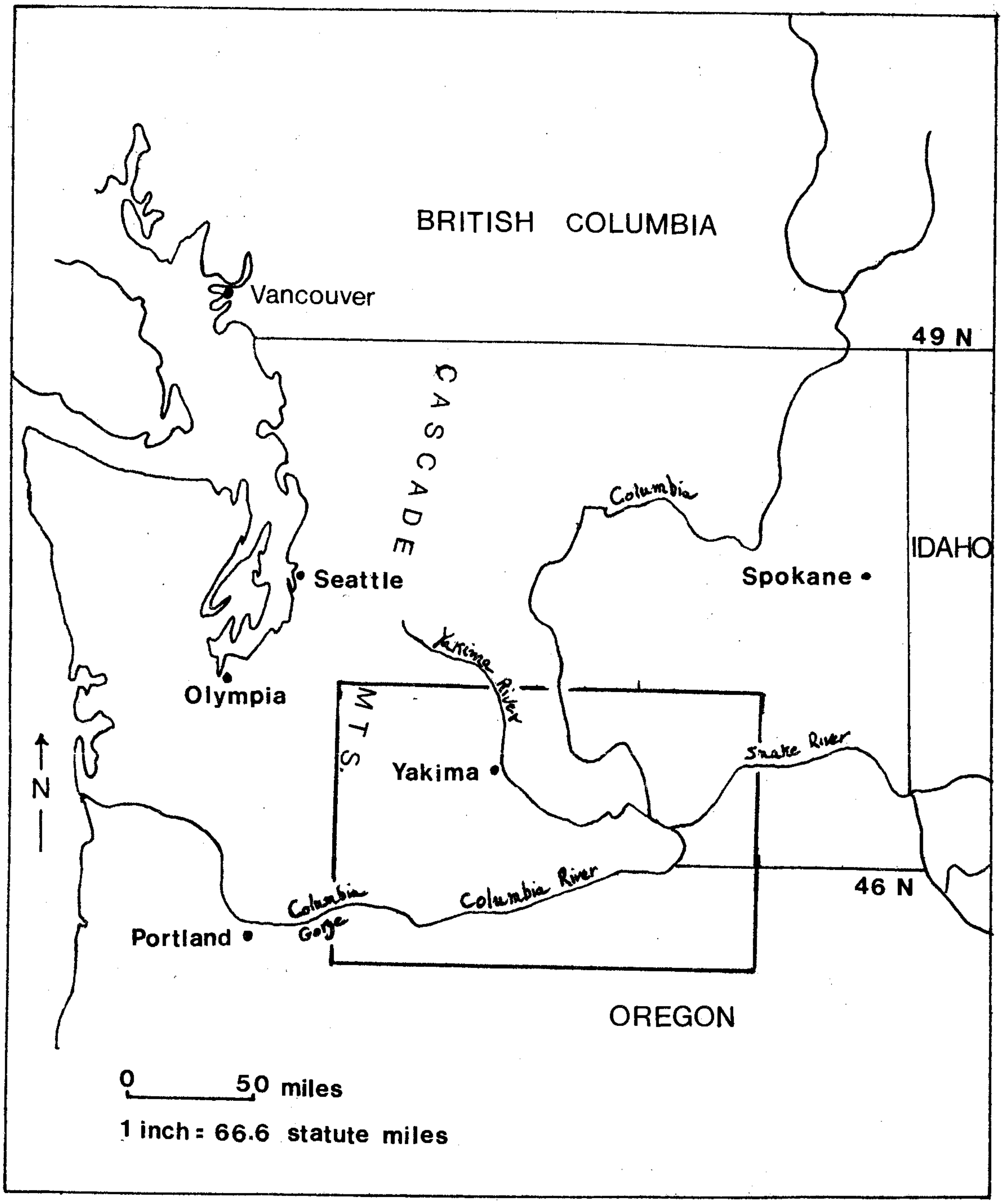

Fig. 1. Northwest U.S. and southern British Columbia
Inset: see fig. 2.

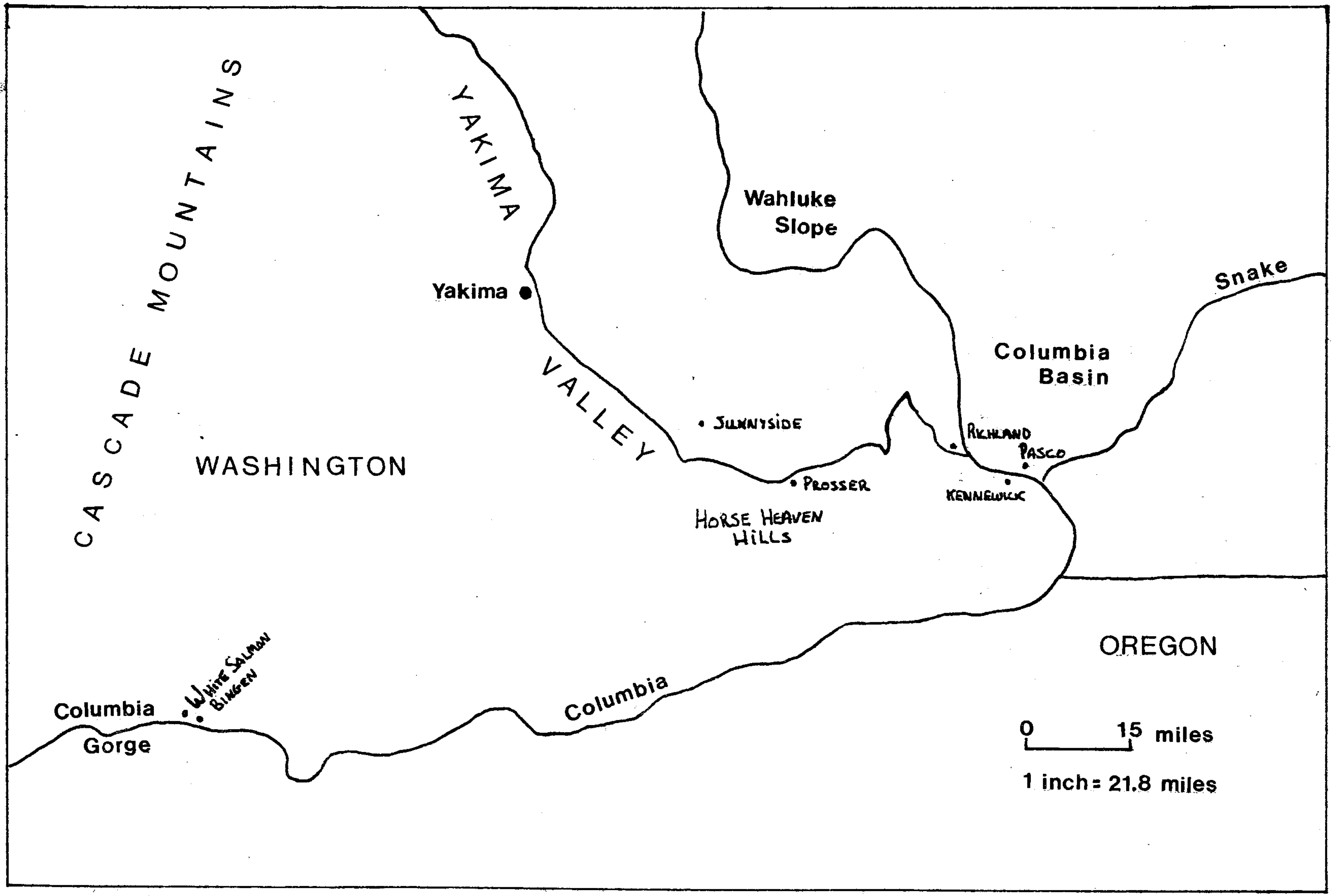

Fig. 2. Wine grape region of central Washington.

Varieties and Site Selection

Grape variety trials were started in 1937 at the Irrigated Agriculture Research and Extension Center (I.A.R.E.C.) in Prosser (Powers *et al.* 1981), where more than 200 varieties have since been grown and evaluated. The U.S.D.A. Agricultural Research Service and the Economic Development Administration of the U.S. Dept. of Commerce in the early 1970s sponsored research by W.S.U. to demonstrate the adaptability of certain wine grapes to Washington and to foster the development of this industry in the Pacific Northwest (Powers *et al.* 1981). These research efforts generated many publications on climate and site adaptability. In 1976, the Tri-State Wine Grape Demonstration Project (ID,WA,OR) was funded, and one of its objectives was the evaluation of selected sites for growing wine grapes (Powers *et al.* 1981).

Researchers from W.S.U. evaluated 10 vineyard sites. Some of these were commercial sites and some were previously established experimental vineyards. They covered a range of climates from a maritime climate west of the Cascade Mountains with only 1700 heat units to a semi-arid climate with about 3200 heat units. Elevations across the study sites range from 455' to 1500' above sea level. Five varieties were chosen. Two red varieties, Pinot Noir and Merlot and three whites, Gewurztraminer , Chardonnay, and White Riesling, were chosen because they were desirable and available in established vineyards. They are also varieties which vary in ripening date: Pinot Noir, Chardonnay, and Gewurztraminer in the early season, and Merlot and White Riesling in the late season. Because the major objective of this study was to evaluate the fruit quality from several different sites, the wine making procedures were standardized as much as possible. Wines from the various sites were submitted to a taste panel and scored (Powers et al. 1981).

The results showed slope and solar radiation to be the important site considerations. A south facing slope is preferred, because it increases exposure to the sun and hence favors heat accumulation. A 10% slope at 46N Lat. receives as much radiation as does level land at 40N Lat. Most importantly, late season radiation, essential for proper ripening of the grape, is much greater on a south slope than on non sloping land (Powers et al. 1981).

All varieties tested reached sugar levels acceptable for wine production. Exceptions occurred at the maritime site, which was the coldest under consideration in the study. In some instances, overcropping resulted in unacceptably low sugar levels. This circumstance causes the producer to postpone the harvest until sugar levels are acceptable, increasing the chance of fruit rot due to possible fall rains as well as lengthening the exposure to predation by birds. For these reasons and others, improper site selection may increase the incidence of pest problems.

Some varieties appear to produce good wines in all the sites considered , but others should be restricted to certain sites. For example, data suggest that White Riesling can be successfully grown throughout the central Washington study area. By contrast, Gewurztraminer produced wines with wide ranges of pH, indicating that site affects the wine quality of this variety and should be considered before planting. Chardonnay and Merlot seemed well adapted to all the sites that were studied. Of the five varieties tested, Pinot Noir was the only one not well adapted to central Washington. It received its highest scores from grapes grown in the Columbia Gorge at White Salmon.

There are other important criteria. Length of growing season must be a minimum of 150 days, with 180 very desirable. The average date of the last spring frost should be prior to April 15 which corresponds with bud-break. A minimum of 1800 heat units are necessary, 2000 to 2500 are desirable, and more than 3000 are needed for late maturing varieties.

At present the industry is based mainly on 11 varieties of vinifera, although an additional 24 have been planted commercially on a small scale(less than 100 acres/variety) as of 1981 (Folwell et al. 1982).

The major varieties are:

Whites	Reds
White Riesling	Cabernet Sauvignon
Chenin Blanc	Merlot
Chardonnay	Grenache
Gewurztraminer	Pinot Noir
Sauvignon Blanc	
Semillon	
Muscat Canelli	

As of 1981, these varieties accounted for 6416 acres or 97% of the total European grape acreage in Washington. The increase of 1500 acres in the last two years has probably had little effect on this percentage, because most of the planting has been confined to these varieties.

European hybrids accounted for only 15 acres in 1981; the varieties represented are Aurora, Cascade, Baco, and Foch. This figure is down from 1978, when 82 acres were planted to European hybrids (Folwell _et al._ 1982). The trend is quite evident. In an area such as Washington, well suited for vinifera production, there is little incentive to plant hybrids that will produce an inferior wine, unless this course is the only solution to climatic or pest problems. Hybrids are well suited to areas with extreme winter conditions and phylloxera infestations, since they are somewhat tolerant of both, but they cannot compete in flavor with vinifera. Hence, in Washington, where the winters are not extremely severe, and phylloxera is not considered a threat at present, pure vinifera is the species of choice.

White Riesling dominates the acreage with 1986 acres planted as of 1981, representing 30% of the total in European grapes. Cabernet Sauvignon, Chenin Blanc, and Chardonnay each cover about 750 acres. There are 450 acres of Gewurztraminer, 378 of Sauvignon Blanc, 367 of Semillon, 351 of Merlot, 158 of Grenache, 169 of Muscat Canelli, and 110 of Pinot Noir (Folwell et al. 1982). The industry is dominated by white varieties which account for 75% of the European acreage.

Economics

The establishment of a vineyard is a capital intensive proposition, since the money is tied up for three to four years before any income is generated from the investment. According to Daniel Kirpes and Raymond Folwell, agricultural economists from W.S.U., "those involved or interested in the production of wine grapes in Washington are no longer asking questions about the technical and economic feasibility of producing wine grapes. Rather, they are seeking economic information about the cost and financing requirements of varying sizes of vineyards and wineries as well as alternative production methods or technologies" (Kirpes and Folwell 1983). When considering the economics of wine grape production in this area, I shall refer solely to an extension bulletin for 1983, which was prepared by the W.S.U. economists named. I rely heavily on this publication because it is up-to-date, area specific, and strong in detail. My main reason for stressing the economics of wine grape production is to make the reader aware of the high cost of vineyard establishment and production, and also to place the costs of pest control in perspective, so that the reader has a clear idea of how these costs relate to total production costs.

The production costs estimated here are based on a hypothetical, owner-operated, 60-acre farm, with 50 acres in vines of the top eight varieties, planted in equal amounts. The vines are planted at a density of 726/acre in 6' by 10' spacing. The land is assumed to be owned by the operator and the machinery is assumed to be new and valued at current market prices.

The total cost/acre in the year of establishment in 1983 dollars is $1661. The largest portion, $502, is the planting cost. Purchasing, setting, and anchoring the end-posts represents a total of $277. An irrigation system is installed, and this cost of about $1000/acre is spread over the first four years, representing $256 in the first year. The only pest control cost in the first year is weed control, which consists of spraying oryzalin (Surflan), a residual herbicide, in April, hand-hoeing in June and July, discing to prepare the soil for a cover crop, and planting the cover crop in May. The cost of the weed control measure is $202/acre, which represents 12% of total production costs for this year.

Total production costs for the second year are $3321/acre. Approximately half of this cost involves setting wooden line posts and stringing the first wire. The irrigation cost is the same pro-rated figure of $256/acre. Lost interest income on accumulated investment of $1661 at 13% accounts for a cost of $216. Labor costs are high in the second year because so many labor intensive duties are carried out. These include setting posts, and training and pruning the vines. Pest control costs for this year are $70/acre. This includes one application of napropamide (Devrinol) for weed control in April ($31), an aerial dusting of sulfur for powdery mildew control ($9), and hand hoeing in mid-summer ($30). Pest control represents 2% of total production costs.

Total production costs for the third year are $2085/acre. The $647 lost to interest on accumulated investment represents the largest single cost. The cost of irrigation is again $256. Pruning, which is labor intensive, involves a cost of about $185. Final work on trellis construction is completed in this year at $120/acre. A small crop can be harvested in this season at a cost of $130/acre. Pest control costs are estimated at $121/acre. This includes one application of napropamide for weed control ($33), two sprays of captan WP (wettable powder) near bloom to control bunch rot ($33), three aerial dustings of sulfur for powdery mildew control ($27), one application of parathion for insect control ($22), and application of Mesurol covering 10% of the vineyard area for bird control ($6). The study does not elaborate on the insects controlled by parathion, but I presume that leafhoppers are the target insect since they are the most common pests and the Spray Guide for Grapes in Washington (Anon.1983a) recommends parathion for their control.

Total pest control costs for the third year are $121/acre, or about 6% of total production costs for this year.

Total costs for the fourth year are $2261/acre. At this stage, the vineyard should be in full production and most of the activities are dominated by cultural practices, since establishment of the vineyard is complete. Money lost to potential interest on accumulated investment again accounts for the most costly single item at $743. Harvesting costs are $353/acre. The final payment on the irrigation system of $256 is made. Pruning costs are about $185/acre. Pest control costs are at their highest since the first year. One application of napropamide and spot treatment with glyphosate amounts to weed control costs of $40/acre. Bunch rot control is attempted with two applications of captan around bloom at a cost of $41/acre. Four aerial dustings of sulfur account for $36/acre. Insect control costs are again $22/acre, and finally, bird control, if attempted with Mesurol, costs $6/acre. Pest control costs of $145/acre in this year represent 6.5% of total production costs. See table I for a breakdown of pesticide costs.

Table I Breakdown of pest control cost/acre by pest categories in relation to production costs for vineyards in Washington. Based on Kirpes and Folwell(1983)

Vineyard age (yrs)	Pest cont. operation	A Cost ($/ac.)	B Total prod. cost ($/ac.)	C Variable prod. cost ($/acre)	A/B	A/C
1	Weed cont.	202	1661	1107	12%	18%
2	Weed cont.	31				
	Mildew	9				
	Hoeing	30				
		70	3321	2584	2%	3%
3	Weed cont.	33				
	Botrytis	33				
	Mildew	27				
	Insect	22				
	Bird	6				
		121	2085	927	6%	13%
4	Weed cont.	40				
	Botrytis	41				
	Mildew	36				
	Insect	22				
	Bird	6				
		145	2261	967	6%	15%

Total production costs over the first four years thus come to about $9328/acre. Pest control efforts over this period are $538/acre or about 5.7% of production costs. Annual pest control costs range from a low of $70/acre to a high in the first year of $202/acre. Although the only pest control effort in the first year is weed control, this effort is critical in getting the vineyard off to a good start, by reducing strong competition from weeds. A realistic average annual pest control cost in a mature, producing vineyard would probably be about $145/acre as estimated by Folwell. Nevertheless, there is considerable variation between vineyards. Some vineyards already in production have yet to encounter pests that are quite common on other sites. Vineyard location and proximity to other crops are probably key factors that determine the pest complex at this juncture. It is also important to realize that Folwell's study did not cover certain pests and for this reason, pest control costs may be underestimated. For example, some growers have reported substantial losses to cutworms in the first year of establishment. The vines are planted in April after a February discing aimed at weed control. The discing may destroy the cutworm's food sources and result in the movement of cutworms to the newly planted vines. Cutworm damage usually occurs between April and June. The damage may be the loss of shoot growth and even death of the plant resulting in a necessary replant (Anon. 1983a). Loss of one season's growth extends the pre-production period by a like amount, causing the producer to wait one more year before his investment begins to pay off. In addition to this loss of time, he will have further replant and control costs. Cutworms tend also to be an unevenly distributed pest of mature vineyards, but the cost of control was not estimated in this study.

An important consideration, which has a substantial impact on pest control costs is choice of chemical. Several alternative chemicals are used now which are more expensive than those referred to in Kirpes and Folwell's 1983 study. Examples are the likely replacement of sulfur by bayleton, a systemic fungicide used extensively for powdery mildew control during the 1982 season. Where this compound is used, the material cost will be about $10 more per acre treated. However, there may be little difference in total costs, which depend on the number of applications made with each fungicide and the method of application. Few growers reported using parathion for insect control in my survey. Most growers prefer dimethoate, a systemic organophosphate, for leafhopper control. This chemical is better suited to the insect's feeding method than is parathion, and is probably more effective. Its use results in a material cost increase of $4 to $18/acre depending on the number of applications necessary for control. I am not at present weighing the effectiveness of one treatment <u>versus</u> another, but simply comparing their costs.

In arriving at an average total production cost, Folwell's study is most valuable, particularly as a guideline to producers. I have suggested some adjustments, mostly in material costs of pesticides, because of the use of alternative and more expensive pesticides by several growers. I have also made the point that some pests encountered in the field and hence their control costs are not mentioned. Nematode control, which can be very expensive, is not considered primarily because there are at present no chemicals registered for use in established vineyards. However once the economic impact of this potential pest is better understood, nematode control may be considered cost effective.

It is important to realize the variation in pest control costs reported in the survey. The lowest estimate by a grower for pesticide material cost was $25/acre, and the highest was $125/acre. This wide range reflects the youth of this industry and the range of pest fauna between vineyards. In general, the older the vineyard, the more pest species are associated with it, the higher the pest control costs, and the greater the potential for increased sophistication in pest management.

Local Industry Outlook

The economic outlook for the Washington wine industry is a function of supply and demand. 1982 was a good year for grape production in the U.S. with increased production over 1981. California production of table and raisin grapes has an important bearing on the Washington industry (Folwell 1982).

European varieties used for wine in California were up from 1.8 million tons in 1981 to 2.2 million tons in 1982. Raisin grapes which are also used for wine, were likewise up from 1.8 million tons to 2.5 million tons. The 1982 season saw increases in the New York wine grape crop as well (Folwell 1982). Production rose in Washington also, since about 1200 acres planted in 1978 came into full production in the 1982 season. With an additional 4500 acres planted since 1980 (Folwell 1982), production in 1985 should be more than twice the current level. Wade Wolfe (1982) of Chateau Ste. Michelle, predicts yields based on total acreage planted now at 43500 tons annually. The current capacity of wineries in the state is about 25000 tons. It is obvious that winery capacity needs to increase substantially in the next few years, or out-of-state sales of grapes need to increase. It also seems painfully obvious that prices paid for grapes will soften, given the imbalance between supply and demand. The current price structure for wine grapes in Washington was developed after the '78-'79 winter when supply was low (Wolfe 1982). Many contracts are expiring now and others will expire over the next few years. These new contracts will be renegotiated based on projections of the availability of grapes (Wolfe 1982). Wade Wolfe has encouraged growers not to plant more acreage unless they have a contract for the production from that acreage.

Growth in U.S. sales of wine from all sources in 1982 was 4.1%. Imported wines grew 7.8% in sales compared to domestic wines which grew 2.8%. Dr. Folwell attributes this reduction of market share of the U.S. products to foreign competition, state of the economy, and the nature of the U.S. wine consumer. High-priced, high-quality, Washington-produced varietal wines have a difficult time competing with good European wines that are priced lower.

This overall supply and demand situation has led to large inventories, which translate into softening prices paid to grape producers (Folwell 1982). Folwell points out that winery capacity is on the increase, but whether this growth will be enough to meet the local grape supply remains unclear.

Another consideration which Folwell addresses is that since 1970, the market share in Washington of locally produced wines has been decreasing. The current share by in-state wineries of the local market is only slightly greater than 4%. One of the most important challenges facing the industry now is to improve the marketing of Washington wines both in the state and elsewhere. Washington is a relatively new viticultural region that is currently experiencing some growing pains. The advice from local agricultural professionals to growers concerning expansion is logical and straightforward: avoid planting more acres to wine grapes unless there is an assured sale for them. If this advice is heeded, the result will be fewer acres planned and planted in the near future.

The current prediction for this industry suggests increased competition between growers to produce a consistently high quality crop, in order to insure a buyer for the grapes.

Optimizing production efficiency now, more than ever, should be a high priority goal for producers. Wineries are currently in a position that allows them to be selective in their choice of producers. Pest control costs and efforts should be more closely monitored than I believe they are now. Proper choice of chemicals and especially the effective timing of pesticide application should result in savings to growers. The profit margin for the grape producer should decrease with a softening in grape prices, making close scrutiny of inputs a necessity. A pest management specialist providing a service to several growers would develop a good overview of pest control in the industry as a whole, and could relate his observations to the individual producer on a regular basis, and so aid in making wise pest management decisions. In short, I think that the current market situation favors the development of any service which aims to optimize production efficiency, and this has to be an objective of any independent pest management service.

III. Pest Complex

Major Insect Pests

Leafhoppers

The grape leafhopper, *Erythroneura elegantula* Osborn (Homoptera:Cicadellidae), has been reported in California, where it is native, since 1864. It is a consistent pest in most vineyards of California and about half the wine grape vineyards need treating in the average season. Some vineyards never need treatment (Flaherty *et al.* 1982). Of 32 growers surveyed in Washington, 13 treat regularly for this pest and 11 of 32 consider leafhoppers to be one of the three most persistent pests encountered. Leafhoppers are the most important insect pests in Washington vineyards at present, according to Hirschfelt (pers.comm. 1983). The most recent published work on leafhopper species in Washington (1955) identifies two species as pests of grapes. They are *E. elegantula* and *E. ziczac* Walsh (Cone pers.comm. 1983), and the former is the most important economically (Wolfe 1955). Research, primarily on species identification, is now underway and will be supervised by W.S.U.. In the Okanagan valley of British Columbia, *E. ziczac* is the only leafhopper species that has been observed as a pest on grapes (McKenzie & Beirne 1972).

Leafhoppers overwinter as adults in the vegetative litter of the vineyard floor in a state of reproductive diapause. Most stay in the vineyard area or in close proximity. They remain in diapause until the day length reaches 11.6 hours, when the reproductive organs begin to mature. The ovaries do not mature completely until the female has fed on the foliage of grapes, the primary host plant of this insect. Adults will feed on weedy growth in the vineyard until the preferred grape foliage is available (Flaherty et al. 1982).

Three generations are completed in California but only two in Washington (Anon. 1983a). The eggs are laid singly on the upper and lower leaf surfaces in the early spring over a period of about six weeks. Eggs of the first brood hatch in about three weeks depending on temperature, and the 1st instar nymph emerges to feed on the underside of leaves. Development from hatching to adult stage takes about 2-3 weeks in California. There is considerable overlap in the 2nd and 3rd generations and all stages can be found on the vines from late May through the summer. Brood development is dependent on temperature. The accumulation of 980 day degrees above 50.5F is required to complete one generation (Flaherty et al. 1982). In Washington, eggs hatch from mid-May to the end of June and new adults are active by the middle of June. Eggs of the second generation are laid in early July, hatch by mid-July, and the adults are active in the vineyard until late fall (Anon. 1983a).

Leafhoppers injure the grape plant by feeding on the mesophyll layer, sucking out the contents of individual cells. Leaves that are fed on heavily will lose their green color, dry up, and fall from the vine. The effect of fewer leaves is a reduction in photosynthetic efficiency, which can result in reduced fruit sugar and consequent postponement of harvest until sugar levels are adequate. Defoliation studies carried out in California indicate that vines can tolerate up to 20% leaf loss per month after fruit set with no effect on yield. The later generations are usually the most damaging because the populations are larger and all stages of the insect are present at the same time, making control more difficult (Flaherty et al. 1982). To the wine grape producer, lower sugar levels translate into less money for the crop.

In heavy infestations, the wood may not mature properly so that buds or canes are susceptible to winter kill. In a severe infestation near Oliver, B.C., the leaves turned brown and dropped before harvest. The grapes were stunted and low in sugar (8-9%). The desired sugar level is usually between 20 and 25%. In addition, leafhoppers can be an annoyance to pickers at harvest. Losses due to this pest in California are described as the cost of treating plus the insect and spider mite disruptions that may occur as a result of treatment.

The 1983 Spray Guide for Grapes in Washington (Anon. 1983a) is the grape production guide developed by Cooperative Extension through W.S.U., and it is the most accessible local reference material for pest descriptions and treatment recommendations. The guide recommends a delayed-dormant application of parathion and oil directed to the trunk and main laterals of the vine for control of leafhoppers. It is suggested that this treatment will also control mealybug, cottony maple scale, and give partial control of cutworms. A late spring application of parathion is recommended as needed from mid-May to June, which coincides with the egg hatch period and is directed at the nymphal stages. Parathion is also recommended as a late season control up to two weeks prior to harvest.

Field studies in British Columbia have indicated the presence of predators on all stages of leafhoppers, and most importantly a small egg parasite, <u>Anagrus</u> <u>epos</u> Girault (Hymenoptera: Mymaridae). This is an important, naturally-ocurring parasite in some California vineyards as well, sometimes eliminating the need for chemical treatment. The <u>B.C.</u> <u>Grape</u> <u>Production</u> <u>Guide</u> <u>1983</u> (Anon. 1983b) stresses that excessive rates or unnecessary insecticide applications will reduce the numbers of these beneficial insects. It recommends an early spray to reduce the later buildup of leafhoppers, aimed at the first generation nymphs. Recommended time of treatment is when 80% of the 1st brood eggs have hatched. Recommended chemicals are azinphos methyl, endosulfan and carbaryl, which is considered to be fairly non-toxic to leafhopper egg parasites. There is also evidence of leafhopper egg parasitism by <u>A.</u> <u>epos</u>

in vineyards in Washington (Hirschfelt pers.comm. 1983). This natural mortality factor, which has been studied in both British Columbia and California is worth considering in greater depth. Taking advantage of this parasite is an important part of pest management in California, and will probably become important in Washington.

In California, the grape leafhopper is a well established part of the fauna on the native wild grape, Vitis californica Bentham, which is found along stream banks. Naturally, the leafhopper is also a part of the artificial agricultural ecosystem in vineyards, which offer additional food. The eggs of the leafhopper can be attacked by A. epos in the early spring. The wasp overwinters in Rubus species, parasitizing Dikrella cruentata Gillette, a non-pest leafhopper which feeds on the native trailing blackberry, Rubus ursinus Cham. and Schlecht, and the Himalayan blackberry, Rubus procerus Muell. This leafhopper is the essential year-round host of the wasp, allowing it to build its population in the early spring. This population buildup is well timed with the activity of E. elegantula in nearby vineyards, and large numbers of wasps leave the blackberry thickets to parasitize newly deposited leafhopper eggs in the vineyard. In areas where vineyards are near the endemic Rubus ecosystem, parasitism stays between 80 and 99% from June to September, eliminating the need for chemical control. A. epos is an effective parasite, completing three generations to one of the leafhopper, and is an important natural control factor in many vineyards of the Napa and northern San Joaquin valleys in California. However, in the southern San Joaquin valley, which has a more arid climate, the vineyards are miles away from native *Rubus*, and parasitism by this wasp occurs late in the season if at all (Doutt and Nakata 1973). Efforts have been made to establish blackberry refuges near vineyards, but they have met with limited success because the blackberry foliage, due to the lack of overstory sheltering, dries up and will not support *D. cruentata*, the essential overwintering host of the wasp (Flaherty *et al.* 1982).

Leafhopper eggs that have been parasitized by *A. epos* are recognized by a reddish or purplish color and the extent of parasitism is a factor that helps determine the necessity for and timing of insecticide applications in California. This parasite has been studied by McKenzie and Beirne in the Okanagan valley in British Columbia. Here it was found to attack eggs of *E. ziczac* in vineyards. Parasitism ranged from 21 to 70% in eggs collected and from 0 to 100% on individual grape leaves. In this area, *A. epos* is thought to overwinter on wild rose, attacking the leafhopper, *Edwardsiana rosae* L., and on apple trees, attacking the apple leafhopper, *Typhlocyba pomaria* McA.. In vineyards that had wild rose or apple nearby, parasitized eggs were found early in the spring, whereas in vineyards that were surrounded by more desert-like conditions, with no wild rose nearby, parasitism was about one month later in the season. Two cultural practices were recommended to help control leafhopper populations: destroying overwintering sites through clean cultivation in and near the vineyard to reduce adult survival; and providing the parasite with overwintering sites by growing their host plants, wild rose and apple, in or close to the vineyard (McKenzie & Beirne 1972). Those are certainly worthwhile considerations in Washington as well, and the realization of a potentially valuable parasite in addition to the presence of other beneficial insects must be considered when determining the necessity, choice, and timing of insecticide applications.

Research and experience in California has led to monitoring systems for leafhoppers based on nymphal counts on foliage, which, when considered along with percentage parasitism, determine the need for chemical treatment. Sampling procedures have been developed for both small (less than 40 acres) and large vineyards. One person can survey 500 to 1000 acres in a day. Late maturing varieties need special attention late in the season, because continuing vegetative growth will attract leafhoppers, possibly resulting in the need for spot treatment. The effectiveness of spring cultivation is limited in farming areas where there are surrounding overwintering sites for leafhoppers such as hayfields, weeds, and grain. Spring cultivation may also complicate cutworm problems, but still should be considered as a tactic in some situations. Trap crops have been tried in California in the early spring before the vines leaf out, but there are few chemicals available that will control the adult stage. Most workers agree that if needed, chemical treatment should be timed for and directed at the 1st brood nymphs, when they are flightless and susceptible to many insecticides. There is also little generation overlap at this time.

Leafhoppers, like many insects, develop resistance rapidly, and therefore it is important to use insecticides only when necessary to extend their effective use period. Using appropriate insecticides that are suited to the insect's feeding behavior and thus are selective, will reduce the impact on naturally ocurring predators and parasites. Dimethoate, a systemic insecticide which is presently under temporary use permit in Washington, is being used now by several growers for leafhopper control. It is well suited for sucking insects and gives good control of thrips as well as leafhoppers and should have less harmful effects on beneficial insects by comparison with the present recommendation of parathion.

Cutworms

The spotted cutworm, *Amathes c-nigrum* L., and the redbacked cutworm, *Euxoa ochrogaster* Guenee (Lepidoptera: Noctuidae), are the major early season grape pests in Washington (Wright and Cone 1980). Of 32 growers surveyed, 16 treat a portion of their acreage each season to control them. Cutworms are a potential pest in both newly established and producing vineyards. Their nocturnal feeding habits complicate detection for those who are unfamiliar with this behavior, or unaware of the potential threat.

Cutworms overwinter as quiescent larvae in soil, trash, or grass clumps. They begin feeding at night in the early spring on weeds, particularly mustard, and also on the grape buds and young shoots. Feeding on buds begins in April and damage can continue into June (Anon. 1983a). Howell (1979) found that there were two generations of spotted cutworm larvae per year in the Yakima valley, with the second overwintering and completing their development in the spring. The larvae are omnivorous, feeding on many crop and non-crop plants including: fruit trees, sugar beets, raspberries, hops, asparagus, potatoes, knotweed, smartweed, lambsquarters, pigweed, morning glory, and Canada thistle. Howell describes these insects as chronic pests due to their non-selective feeding habits, and sometimes as acute pests during specific periods. At present it is easier to survey for adults than for larvae. Howell used blacklight traps to determine flight periods. The first adult flight is from May to June. There is an absence of adults in July. The second flight period is from August through October. In five years of study in the Yakima valley, the second flight was always larger than the first, but second flight population size could not be correlated with that of the first flight. The factors controlling population growth and decline have not been identified in the area, although it is thought that population changes are dependent on environmental factors rather than cutworm density (Howell 1979).

Both of these Noctuid species feed at night, but only the redbacked cutworm returns to the soil for protection during the day. The spotted cutworm seeks protection during the day under bark on the vine and trunk (Flaherty et al. 1982). It is only the overwintering larvae that damage mature vines by feeding on buds and new shoots. Later in the season, grape foliage is too vigorous to be threatened by these insects. Adults lay eggs mostly on leaves of plants fairly close to the ground (Flaherty et al. 1982).

Cutworms damage vines by feeding on young buds and new shoots less than 6 in. in length. Damage to newly planted vines results in loss of shoot growth and therefore nothing to train to the low wire, or in death of the plant if all growing points are removed (Anon. 1983a). One of the growers surveyed reported extensive damage to a newly planted vineyard, resulting in the need to replant several acres. Damage to producing vineyards results in loss of fruit production due to the destruction of the buds responsible for grape clusters. Studies in California show that very high cutworm populations can reduce yield as much as 80%.

Wright and Cone (1980) studied the response of V. labrusca (cv. Concord) to cutworm damage, simulated by removing primary buds and then relating the bud removal to yield loss. Economic damage levels were also determined, based on cost of treatment, yield decrease per bud lost, and market value of fruit. There was no attempt to relate cutworm numbers to yield loss, but it was shown that very few cutworms could result in substantial damage necessitating chemical control action. When all the primary buds were removed, the yield was reduced by from 40 to 62.6%. The vine compensates for primary bud removal by increased growth from secondary buds, but less fruit is produced per bud, and hence yield is reduced. If both primary and secondary buds are removed, then no fruit is produced. Vines which are damaged in one year will compensate the following year with increased fruit production which may almost make up for the original yield reduction (Wright and Cone 1980). The major factor that determines economic damage resulting from bud removal is yield per bud, which may vary substantially. Treatment is cost effective in Concord grapes with 1 to 5% bud damage (Wright and Cone 1980). Economic damage levels in vinifera would be reached at lower bud removal values, because of the higher fruit value. Economic damage levels in vinifera are affected by market value, variety, sugar levels, cost of treatment, and yield. The important contribution of Wright and Cone's study is the realization that a small loss of bud tissue results in a large loss of yield. It would be very useful to be able to monitor the cutworms and relate their density to vine damage and need for treatment.

The Washington spray guide (Anon. 1983a) recommends spraying methomyl to cover the foliage and fruit in areas which had cutworm problems in the previous season, or in areas where cutworms are present and 5 to 10% of the buds are damaged. Control efforts must be timed with bud formation in April and May. Control is complicated at present (1983) by registration limitations on some of the most effective chemicals (Anon. 1983a). Of 16 growers who treat for cutworms, 5 used methomyl and it was the most commonly chosen chemical. Also reported were carbaryl bait, *Bacillus thuringiensis*, chlorpyrifos, and parathion.

In a Michigan study (Marmor, Howitt, and Olsen 1981), various insecticides (monocrotophos, fenvalerate, permethrin, acephate, chlorpyrifos, methomyl, and carbaryl) were compared for control of *A. c-nigrum* and *Euxoa* species. Methomyl gave the poorest results of all chemicals tested. Pyrethroids were recommended because they have a negative temperature coefficient of toxicity against insects, which is important because cutworm control is most effective when it is applied in the evening in the early spring. The pyrethroids performed well in both mature and non-producing vineyards. Chlorpyrifos has an added advantage in its soil residual action, when compared to the synthetic pyrethroids. Baits provided good control, but they tend to deteriorate rapidly in wet weather or under irrigation. In addition to poor reduction of bud damage by methomyl, this insecticide has an oral LD-50 of 17-26, placing it in the high to extremely high toxicity range (Miller and Craig 1980). The Washington spray guide also recommends against discing the cover crop in early May because this action will intensify cutworm damage to vines.

The B.C. Grape Production Guide 1983 (Anon. 1983b) recommends spraying either azinphos methyl or carbaryl on the vegetation at the base of the vine as well as on the vine and grape foliage, when feeding damage is observed on non-bearing vines. In work by Dibble et al. (1979) in California, carbaryl was the most effective chemical of ten tested for cutworm control.

Natural enemies are especially important in keeping cutworm populations in check (Winkler 1962). Some tachinid flies and braconid wasps parasitize cutworms, which are also commonly preyed upon by ground beetles. "Natural enemies provide the most important control of spotty infestations of cutworms on grapes within vineyards and in grape growing districts" (Flaherty et al. 1982).

Grape Pest Management (Flaherty et al. 1982), a large booklet published by the University of California, outlines a monitoring strategy for these insects. The grower is urged to keep a record of years when cutworm feeding is most intense, map areas of cutworm activity within the vineyard, and observe bud damage or presence of larvae in early spring. This publication outlines methods to quantify bud damage by randomly selecting six locations within the vineyard and counting any damaged buds on ten adjacent vines at each location. Treatment is cost effective if an average of more than 2 buds per vine are damaged out of the 60 vines examined. If fewer than 2 are damaged, sampling is repeated in 3 to 4 days until the shoots average 6 in. long. This method and the economic injury level apply only in the North San Joaquin valley and the Central and North Coast valleys in California. This estimation of economic injury level is lower than that referred to above by Wright and Cone (1980), and supports their contention that what may appear to be only slight damage, is enough to warrant treatment.

In addition to the chemical controls mentioned and proper timing of discing the cover crop, there are some other cultural practices which may be helpful. Weed removal in late summmer or fall reduces both food for the cutworm larvae and sheltered locations for adults to lay eggs. Control of perennial weeds such as field bindweed and Canada thistle in the early spring has helped to reduce the impact of the red-backed cutworm in asparagus fields in Washington. When these early season weeds are not present, cutworm mortality increases and hence fewer survive to attack the later emerging asparagus spears, which are the preferred food (Tamaki, Moffit, and Turner 1975). A similar situation exists in vineyards, where cutworms feed on early weeds and then move to the vines as the buds swell. Control of weeds in the early spring and fall is a wise cultural practice and should be followed in mature vineyards as well as prior to planting new vineyards. Where furrow irrigation is used, water can be managed so as to bring larvae to the soil surface during the day and expose them to adverse weather. This practice is used extensively in the San Joaquin valley of California, and is quite effective. It could have use in Washington, where some growers use furrow irrigation. Where baits are used, the method of delivery is dependent on the species of cutworm that is present. Topical hand applications of baits will be necessary to control spotted cutworms, which do not return to the soil during the day. The best results have been with apple-pomace bait formulations. Spraying carbaryl early in the season has proven to be quite effective and has little effect on the natural enemies of cutworms or the leafhopper egg-parasite, Anagrus epos (Flaherty et al. 1982), but may encourage buildup of mites (Anon. 1983a, Dibble et al. 1979).

Mites

The major mite pest species in Washington is the McDaniel mite, Tetranychus mcdanieli McGregor, which is mainly a pest of tree fruits in this region. As in orchards, mite populations become intolerable following periods of heavy insecticide application or inappropriate choice or timing of insecticide applications to control other pests. The development of high mite populations is favored by clean cultivation, dusty conditions, high temperature, low humidity, reduced predator effectiveness, and stressed vines (Anon. 1983a, Flaherty et al. 1982). Little research has been done on mites in Washington vineyards. Extensive research has been done in the southern San

Joaquin valley of California on the Pacific spider mite, *Tetranychus pacificus* McGregor. This mite has attained high pest status due mostly to excessive insecticide use for control of various insects including the grape leafhopper (Ali Niazee, Stafford, and Kido 1974, Flaherty *et al.* 1982). It is commonly known that mites, due to their heterogeneity, are able very rapidly to develop populations resistant to pesticides. Outbreaks are often caused by the use of insecticides which reduce the population of the predatory mite, *Metaseiulus occidentalis*. Most of the California research has been designed to identify pesticides that can be used effectively for key insect pest control with minimal disruptions of the predatory mite. *M. occidentalis* is also the most important predator in Washington orchards, and is probably very important in wine grape vineyards.

Mites overwinter as mature females under grapevine bark. The overwintering females move onto young foliage at bud-break and can lay as many as eight eggs per day, of which two-thirds may develop into egg-laying females in ten days or less. The populations increase rapidly under favorable conditions, and many generations are produced in a season (Flaherty *et al.* 1982). Injury results from the mites feeding on leaf tissue which can become brown and dry up, and depending on the extent of damage, lead to adverse effects on fruit quality and maturity (Flaherty *et al.* 1982).

Of the 32 growers surveyed in Washington, 3 treat regularly for mites, and all use the same pesticide, propargite (Omite). This is the treatment recommended by the Washington spray guide (Anon. 1983a) once the economic threshold of 10 to 20 mites/leaf has been reached, or on observation of shoot stunting. However at present, I think that few growers monitor regularly and effectively for this pest. A good preventative strategy to avoid mite problems is to use an ecological approach when managing other insects, particularly the grape leafhopper. Studies in California indicate that methomyl for leafhopper control is less disruptive if treatments are applied late in the season. Its short residual activity allows predatory mites to recover. But first brood leafhopper treatments with this chemical greatly hinder the development of adequate predator populations. Parathion and ethion reduce leafhopper and spider mite populations in California while allowing predatory mites to maintain control of spider mites (Flaherty et al. 1982). A study by Hoy et al. (1979) compared methomyl, dimethoate, and permethrin for grape pest management in the San Joaquin valley. Dimethoate had the least disruptive impact on predatory mite populations when used for leafhopper control, but its effect on other beneficials was not measured, and its long residual activity increases the possibility of disrupting other insects. Methomyl was considered to be moderately disruptive. Azinphos methyl is used extensively in apple orchards in Washington and British Columbia because it does not disrupt mites. Thus, it may have use at some time in vineyards in Washington. Due to the ever-changing regulations and availability of pesticides, it is of limited use in this study to dwell on particular insecticides and their present efficacy. Flaherty et al. (1982) stresses the importance of pre- and post-treatment monitoring to gauge the effects of different chemicals on beneficial and target organisms. In general, chemical control of mites should be delayed as long as possible in order to reach a favorable ratio of prey to predator and allow for maximum distribution of predators within a vineyard. If treatment is necessary, a selective acaricide should be used. To readjust imbalances in prey:predator ratios caused by heavy insecticide use may take as long as four years without chemical applications (Flaherty et al. 1969).

The appropriate time for monitoring mite populations coincides with leafhopper monitoring and involves an estimation of relative population levels based on number of eggs and young on leaves and damage to the vine, as well as knowledge of prey-predator distribution patterns. Eggs and young can be counted with a hand lens in the field (Flaherty et al. 1982). The data, once obtained, are components of the decision making process. Other factors which should be considered are: vineyard vigor, moisture stress, other pests, and timing of harvest.

Mite outbreaks are often localized in the same spot within a vineyard from year-to-year and may be associated with poor drainage and vine stress. "Use of winter and summer cover crops has been noted to improve water penetration in vineyard soils and to lessen these outbreaks" (Flaherty et al. 1982). Vineyards where grass culture is practiced have higher humidities and less dust, and consequently fewer mite problems. "Also a more diverse fauna and improved predation of spider mites have been recorded in vineyards where grasses and other weeds are not removed by cultivation" (Flaherty et al. 1969). Potentially dusty roads should be sprayed with road oil to minimize dust, which tends to increase mite problems. Flaherty et al. (1982) also recommend heavy watering in the early spring to reduce vine stress. Where overhead sprinklers are present, they can be used to keep spider mites under control, but predatory mites are not adversely affected. The judicious use of fertilizer, altering pruning practices,and nematode control all will improve vine vigor and may also reduce mite susceptibility. "Management of spider mites is best accomplished by integrating cultural practices with biological and chemical control" (Flaherty et al. 1982).

Thrips

The western flower thrips, Frankliniella occidentalis Pergande (Thysanoptera: Thripidae), overwinters as mature females in the vineyard litter and in adjacent weedy areas. In the early spring they develop on weeds before moving to grapes to feed on foliage (Anon. 1983a). This insect is generally more of a problem in table than in wine grapes because scarring of the berries from feeding and ovipositing results in culls which are not marketable, or cracked berries, which are susceptible to rot organisms. Flower thrips occasionally cause stunted shoot growth and foliar damage when the shoots are under 12 in. long, but seldom is damage severe enough to warrant chemical control (Flaherty et al. 1982). Only 1 of 32 growers surveyed treated regularly for this insect in Washington. Flaherty et al. (1982) indicate that vineyards with a grass or weed cover are more likely to experience early spring feeding on young shoots than are clean cultivated vineyards.

Economic injury levels have not been determined for this insect in California, but populations can be monitored by striking the grape cluster with a flat piece of cardboard and counting the individuals on the cardboard surface. Stunted shoots are also a good indication of the presence of thrips. Treatment is recommended at early to late bloom in both California and British Columbia (Flaherty et al. 1982, Anon. 1983b).

One application of dimethoate has been found sufficient, and as this treatment is used by some growers to control first brood leafhopper nymphs in Washington, thrips control is often achieved as a fringe benefit (Hirschfelt pers. comm. 1983). In contrast to this control strategy, both Washington and Oregon guides recommend a later season control in July and August if leaf and shoot growth appears to be stunted. Vineyards that receive a delayed-dormant application of parathion and oil for mealybug control may not experience thrips injury (Anon. 1983a). Thrips, though often thought of as pests, have been observed to prey upon Pacific spider mite eggs in California, and in this sense their presence at undamaging population levels may be beneficial (Flaherty et al. 1982).

Black Vine Weevil

The black vine weevil, *Brachyrhinus sulcatus* Fab. (Coleoptera: Curculionidae), is an important European pest of a wide range of horticultural crops in Europe, North Africa, United States, Canada, Australia, and New Zealand. It has a host range of at least 140 plant species, with the damage in most cases due to root feeding by the larval stages (Bedding and Miller 1981). In grapes, the adult is the more damaging stage, feeding on fruit cluster parts and berry pedicels. In the Yakima valley, this insect was first reported on Concord grapes by Frick and Keene in 1957, when growers were experiencing heavy yield reductions. These losses stimulated research by Dr. W. Cone of W.S.U. starting in 1961 to determine the economic impact of this pest and identify levels of infestation where controls were justified. Yield losses were estimated by Cone (1963) to reach 3.45 tons/acre. As of 1961, no controls had been developed for this pest on grapes anywhere in the U.S., so research to identify effective controls was also conducted. Control was achieved with the application of granular aldrin to the vineyard floor, but this chemical is no longer available and at present (1983) chemical control options are limited.

The emergence of adult weevils from the soil begins in late March and usually peaks in late June. All adults are flightless females, each capable of laying up to 500 fertile egs starting three weeks after emergence (Anon. 1983a). Although they cannot fly, they are strong walkers and have been recorded to move 180 ft. in three days (Cone 1965). Adult injury occurs at night, when the weevil leaves protected sites on the vineyard floor to feed on cluster parts. The adult returns to shelter in the early morning because it cannot survive continued exposure to high temperatures. The effect of the early treatments of granular aldrin was to disrupt the normal behavior of the weevil, causing it to remain on the soil surface during the heat of the day which resulted in death (Cone 1965). Due to their nocturnal activity, weevil infestations can go unnoticed for a long time, unless the grower is aware of the risk and detects feeding damage.

Injury includes girdling of berry pedicels and notching or removal of portions of the cluster stem. Single berries or portions of the cluster may be detached completely or weakened so they later fall. Individual berry weight can be reduced by up to 23% (Cone 1963). Potential damage is hard to predict because injury begins immediately after pollination before the grower can estimate his crop load, and girdled or notched berry stems are difficult to see as the cluster enlarges. Injury continues through mid-August when the weevil population begins to decline (Cone 1965).

The first controls used, granular organo-chlorine insecticides directed at the soil surface, were very effective. Application was made just prior to predicted adult emergence, and was effective in 1962 even when applied two weeks before adults began emerging. In that year, injury to grape clusters was reduced dramatically to less than 1% in all plots, compared with injury the previous year ranging from 42 to 75% (Cone 1965). Pre-treatment and post-treatment sampling can be accomplished by taking soil samples under the trellis to measure larval and pupal abundance, or by funnel traps (Cone 1963) attached to the trellis to sample adults. Economic injury levels have not been determined for this weevil in Washington. Cone (1963) found an association between type of cover crop and adult weevil abundance, based on adult trap catches. Catches were highest in plots with creeping red-fescue cover indicating a probable association between black vine weevil larvae and roots of this grass. The association is of interest, as several wine grape vineyards are experimenting with permanent cover crops including fescue. Fruit damage and early season adult weevil counts were significantly lower in vineyards with no cover or with a combination of oats and vetch (Cone 1963).

The present recommendation for control (Anon. 1983a) is one application of flowable carbofuran applied to the lower part of the vine and soil beneath the trellis between May 20 and June

20. The granular form of carbofuran has been effective for black vine weevil control in dryland cranberry bogs in Washington where it is well suited to this crop which forms a dense mat on the soil surface. Granules are able to penetrate this growth and reach the target insect. Drift is not a problem, toxicity to bees is reduced, and access of the chemical to birds is limited. In vineyards, birds would have easy access to this highly toxic chemical if applied in the granular form. For this reason, it is not registered for use in Washington and British Columbia vineyards. Some growers in Oregon have reported success with 2 to 3 applications of malathion or azinphos methyl sprayed on the soil near trunk crowns and on the basal part of the canes once adult weevils are detected. Results are probably best if treatment is applied in the evening (Garren *et al.* 1982). This insect has not been reported as a pest of grapes in British Columbia or California so far, although its presence has been established.

The use of a nematode, *Heterorhabditis heliothoides*, to control black vine weevil larvae in potted plants in greenhouses and nurseries has been quite successful and cost effective (Bedding and Miller 1981). Although hundreds of insects have been proven susceptible to nematodes in laboratory tests, there have been few attempts to use this tactic under normal horticultural conditions. The method may be worthy of further investigation.

Although no grower surveyed reported problems with black vine weevil, it is potentially important in wine grape vineyards in Washington because it is capable of causing extremely high yield losses, and the growing use of permanent cover crops may favor the insect. Although economic injury levels have not been determined, relative population size can be determined from year to year through soil sampling or funnel traps.

Minor Insect Pests

Grape Phylloxera

One of the most widely known aphids, the grape phylloxera, *Daktulosphaira (Phylloxera) vitifoliae* Fitch (Homoptera: Phylloxeridae), is considered to be a major pest of vinifera in many places. The phylloxera is native to eastern North America where it infests the roots and leaves of wild grapes in the Mississippi Valley and the southeastern United States (Flaherty *et al.* 1982). Around 1860, this pest was introduced into France where it destroyed 75% of the vines in 30 years (Winkler 1962). The European wine industry was saved through a preventative strategy; the use of resistant American rootstocks which could tolerate phylloxera-infested soil. Phylloxera was introduced to California at about the same time with cuttings from either the eastern United States or Europe. About 20% of California's grape acreage is infested with this insect now and its area is slowly increasing. Infestations in California are most severe in the North Coast grape growing region because of the predominance of fine textured soils, a factor that favors phylloxera establishment and spread (Flaherty et al. 1982). Soils containing clay expand on wetting and contract on drying. This results in the formation of cracks on the soil surface which allows phylloxera crawlers to enter the soil and locate roots. Increased clay content also allows for more space around roots, so the insect is free to travel the root system where it feeds and forms galls. Natural spread in California has been limited due to the absence of a reproductive winged form, which is capable of laying eggs on leaves resulting in the formation of leaf galls. This winged form is present and normal in the eastern U.S. (Winkler 1962).

Because of the predominance of sandy soils in eastern Washington, phylloxera is not a major threat to the industry, nor is it likely to attain the pest status that it has reached in parts of California. No chemicals have proven effective in controlling this insect. The most effective control is through the use of resistant rootstock, both in already infested soil and in areas of potential infestation. The Washington industry is based on vinifera plantings which are on their own roots and have no natural resistance to this insect. Here, rootstocks will be chosen based primarily on resistance to cold and nematodes (Ahmedullah 1980). Although several of the varieties which are worth considering for use in Washington have moderate to excellent resistance to phylloxera, this is not considered an important criterion now. However, in Oregon, where soil types are more favorable to this pest, phylloxera resistance is an important criterion to consider when selecting desirable rootstocks (Ahmedullah 1980).

Apparently the reproductive winged form is present in the Okanagan Valley of interior British Columbia, and hence, where soil type allows, this insect could spread rapidly and gain high pest status. For this reason, it is recommended to plant vinifera only if it is grafted to resistant rootstock. Both root and leaf galls form on infested French hybrids, but only root galls are found on _V. vinifera_ and _V. labrusca_. French hybrids make up the bulk of the wine grape plantings in British Columbia. Some hybrid varieties have shown increased yields when grafted to resistant rootstock. Prior to planting in a clean site, grape nursery stock in phylloxera infested soil can be treated by dipping in a malathion solution (Anon. 1983b), or in 125-130F water for 3 to 5 minutes (Flaherty _et al._ 1982).

Branch and Twig Borer

The branch and twig borer, _Melalgus confertus_ (LeConte) (Coleoptera: Bostrichidae), occurs throughout California and in parts of Oregon where it is considered a minor insect pest. Of the growers surveyed in Washington, none reported it as a pest problem. When numerous in a vineyard, these beetles can destroy more than half of all canes (Flaherty *et al.* 1982). A sign of infestation is wilted or broken young shoots resulting from a feeding puncture made by the adult beetle in the spring. Newly hatched larvae are only capable of entering dead wood, but once established, they feed also on living wood. Larvae survive the winter in pruned canes in the vineyard and in neighboring shrubby areas or brush piles as well as in the arms of the vine. Chemical control is usually not necessary because good sanitation practices keep the insect below economically important densities. Pruned canes should be burned during the winter, and areas surrounding the vineyard should be kept free of brush piles. When insecticides are used, they are directed at emerging adults in the spring (Garren *et al.* 1982).

Click Beetle

Click beetles (Coleoptera:Elateridae) can cause damage by feeding on developing buds. It is the adult stage that is the sometime pest of grapes, rather than the larval stages, commonly known as wireworms, which inhabit the soil. The beetles feed during the day, leaving a hole in the top of the primary bud. If present, these insects are most probably controlled by sprays directed at cutworms (Flaherty *et al.* 1982). Of 32 growers surveyed, only one reported observing click beetle damage. In this instance, the variety affected was Chardonnay but no treatment was made.

Wasps

Adult wasps, genus Vespula (Hymenoptera: Vespidae), can be a problem late in the season. At this time, grapes are attractive to these insects, which require a diet high in sugar (Garren et al. 1982). Of 32 growers surveyed, one reported difficulty in controlling wasps. The best strategy is to locate and destroy nests in the early spring. Yellow jacket nests that are beneath the ground can be destroyed by pouring gasoline or 1 to 2 quarts of a 1% solution of malathion, diazinon, or carbaryl down the entrance hole. This should be done at night when the wasps are inactive. Yellow jacket nests that are above ground, and hornet's nests, can be treated with an aerosol insecticide directed at the entrance hole for 15 to 30 seconds. Such a product contains pyrethrin, which quickly paralyzes the wasp, and propoxur, to ensure a kill. Nests in trees can sometimes be destroyed by burning (Costello 1980). This strategy requires foresight and time to locate nests, but is the most successful in problem areas.

Where early season control efforts are not made or are unsuccessful, the best tactic is to use attractant traps or insecticide-treated baits on the edge of the vineyard to intercept daily migration. A slow active insecticide such as carbaryl or encapsulated diazinon is recommended because the wasp, once exposed, is able to return to the nest to poison other adult members and young larvae. It is important that baits and traps be selective for wasps. Baits must be freshened every few days to maintain their attraction. Homemade baits of catfood, fish heads or chicken treated with insecticide can be hung around the vineyard. Best results have been attained when bait stations are placed about every 10 ft. (Garren et al. 1982).

Grasshoppers

Many species of grasshoppers (Order:Orthoptera) are potential pests in vineyards, where damage is caused by direct feeding on the foliage. Of 32 growers surveyed, only one reported grasshoppers as a pest. This particular vineyard is surrounded by rangeland and grasshoppers may move into the vineyards as grass species begin to dry up in the late summer. Treating the surrounding rangeland with a poison bait may be feasible in this situation (Flaherty et al. 1982, Garren et al. 1982). The Oregon spray guide (Garren et al. 1982) refers to grasshoppers as occasional pests of newly established vineyards. If the vineyard is surrounded by rangeland, spraying the range vegetation with malathion is recommended.

Grape Mealybug

The grape mealybug, *Pseudococcus maritimus* Ehrhorn (Homoptera:Coccidae), is a major pest of Concord vineyards in Washington, where infestations reduce the market value of the fruit due to honeydew on the grapes and the subsequent buildup of sooty mold. The most effective control is a delayed-dormant application of parathion and oil directed to the trunk and main laterals to control the crawler stage of this insect (Anon. 1983a). This treatment is widely practiced on Concord grapes used for juice, but is not a common practice on wine grapes. Recent work by Shaw (1982) in Washington has determined that the female releases a pheremone to attract males for mating. If this insect becomes of economic importance in wine grapes, it may be practical either to trap out males prior to mating, or to monitor populations by using the pheremone attractant. An alternative strategy for control is the use of poison baits to control ants which protect the mealybug from natural enemies (Flaherty *et al.* 1982).

Cottony Maple Scale

The cottony maple scale, *Pulvinaria vitis* L. (Homoptera: Coccidae), inflicts the same type of damage on the grapes as the mealybug. Control is easy and effective if an insecticide spray is directed at the crawler stage in July. If the main trunk and laterals are infested, control can be achieved by a dormant oil spray in the winter. Only one grower of 32 surveyed reported the occurrence of this pest. It was observed on Pinot Noir, and no control was attempted.

Consperce Stinkbug

The consperse stinkbug, *Euchistus conspersus* Uhler (Hemiptera:Pentatomidae), may move from surrounding areas into vineyards in late summer and fall to suck sap from the leaves and juice from the ripening berries. These insects have a wide host range and it is only when food sources are removed that they will migrate into a vineyard. Cutting an alfalfa field adjacent to a vineyard can result in an influx of these insects. Chemical control is usually directed at the surrounding crop, rather than within the vineyard. Since they are late season pests, chemical treatment within the vineyard is restricted because of possible residue on the fruit (Winkler 1962).

On the following page (Table II) is a list of insect pests identified as problems by vinifera growers surveyed in Washington.

Table II Insect pests reported by vinifera growers surveyed in Washington.[a]

Common name	Latin names [b]	# Growers reporting as problem
Leafhoppers	*Erythroneura elegantula* *Erythroneura ziczac*	13
Cutworms	*Amathes c-nigrum* *Euxoa ochrogaster*	16
Mites	*Tetranychus mcdanieli*	3
Thrips	*Frankliniella occidentalis*	1
Wasps	Hymenoptera: Vespidae	1
Grasshoppers	Orthoptera	1

a Based on response to question #8 in questionnaire

b Particular species listed only in those cases where it could be substantiated through local literature review or communication with specialists in the area.

Diseases

Powdery Mildew

Grape powdery mildew, caused by the fungus *Uncinula necator* is the most commonly encountered disease of vines in Washington. Of 32 growers surveyed, 31 reported that treatment is necessary on a regular basis during the growing season. It has been a consistent problem in California vineyards for over 100 years, and has been treated with regular, timed sulfur applications on a preventative basis for almost as long (Sall, Wrysinski, and Schick 1983). This is still the most commonly used method of control in Washington, but several growers are beginning to experiment with a systemic fungicide, bayleton. Wine grapes are more susceptible to powdery mildew than Concords, and the Chardonnay, Chenin Blanc, and White Riesling varieties are particularly susceptible (Hirschfelt 1981a). If left uncontrolled, a mildew-infested vineyard will be devastated, resulting in a poor quality crop that is low in sugar, susceptible to rot organisms, and of little value for wine production. For these reasons, control efforts are necessary.

The fungus overwinters as dormant mycelium in infected buds. This mycelium will continue to grow in the early spring and spread to new tissue forming a mat of mycelium, from which spores will be produced and liberated to infect other areas of the vineyard. The cycle can repeat itself several times during the growing season. The rate of spread of the disease depends on several factors, the most important being temperature. At the optimal temperature for mycelial growth and spore germination, 77F, a generation, which is defined as development from spore germination to spore production from the colony produced, is completed in five days (Flaherty et al. 1982). Mildew infection can be detected early in the spring with the use of a hand-lens. The first signs observed are small yellow patches about 1/4 inch in diameter on the leaf surface. The mycelium sends short, root-like branches called haustoria into the uppermost layer of plant tissue to remove nutrients. Early signs of infection may go undetected unless vineyards are carefully monitored (Hirschfelt 1981a). Infection is most commonly first observed on young berries growing under a heavy canopy. Infected berries become scarred, stunted, and may crack open, allowing invasion by rot organisms (Flaherty et al. 1982).

The susceptibility to infection of various plant parts changes through the season. Fruit is susceptible from the beginning of development until it reaches about 8% sugar level. Fungus growing on infected berries will produce spores until the sugar level reaches 12 to 15%. Once the berries have reached about 15% sugar, they are immune to infection. Leaves are most susceptible to mildew when they are growing rapidly, and they become more resistant as they age (Flaherty et al. 1982). The disease spreads most rapidly in shaded areas of the vine that are cool and not exposed to direct sunlight, as the disease is favored by moderate temperatures from 65 to 80F (Ahmedullah and Maloy 1979). Leaf temperatures above 90F will kill both spores and mycelium (Flaherty et al. 1982). According to Grape Pest Management (Flaherty et al. 1982), "No accurate generalization can be made concerning the effect of air temperature on powdery mildew, because so many factors relating to vine vigor and canopy density can modify the temperature experienced by the mildew on the leaf surface."

The most effective control of powdery mildew is to prevent infection by covering susceptible plant tissue with sulfur prior to sporulation. The Washington spray guide (Anon. 1983a) recommends the first treatment when the shoots are about 6 in. long. Additional dustings are given at the 12 and 18 in. growth stages and then at two-week intervals. The use of sulfur is often complicated by overhead irrigation. Its use can result in a requirement for an increased number of applications in order to maintain a protective cover. The cooling effect of overhead sprinklers can encourage spread of mildew (Hirschfelt 1981a).

Of the 31 growers surveyed who treat regularly for this disease, 11 use sulfur alone, 9 use bayleton alone, and 11 use a combination of these two fungicides. Growers who use sulfur alone reported the number of applications to range from 3 to 9 per season with an average of 5. Of those using bayleton, 6 considered that two applications were sufficient and 3 reported making 3 applications of this systemic fungicide. Those growers who use a combination of sulfur and bayleton reported a wide variety of practices. At one extreme, a grower reported one application each of bayleton and sulfur. At the other extreme, 3 applications of bayleton supplemented by 6 applications of sulfur was reported. The survey results indicate a substantial variation in treatments for powdery mildew among the respondents. About half the growers surveyed monitor this disease. Of those who monitor, most produce for Chateau Ste. Michelle, and the remainder are large operations with well trained staff available. Monitoring for mildew infection coincides with leafhopper monitoring, and should result in more judicious use of pesticides and better timing. Chateau Ste. Michelle presently uses 3 to 4 applications of bayleton, supplemented by up to 3 applications of sulfur. They think that through effective fruit monitoring, the last application of Bayleton may be eliminated, resulting in a saving of about $25/acre (Hirschfelt, pers. comm., 1983).

Sall _et al._ (1983), realizing the importance of temperature in powdery mildew development and spread, designed a system to time sulfur applications based on this factor. A mathematical model which considered the effect of temperature on vine growth, mildew development, and sulfur effectiveness was the basis for a formula that was tested by 44 growers throughout California to time their treatments. Each grower also treated a portion of his acreage with the conventional preventative sulfur applications, where timing is based on plant growth. Tests were completed in

36 vineyards. In 15 vineyards, the number of applications was the same regardless of the system used to time sulfur applications. In 11 vineyards, use of the formula increased the number of sulfur applications by a mean of 2, compared with preventative scheduled treatments. In 10 vineyards, use of the formula decreased the number of applications by a mean of 2.4. The results were more successful in the inland San Joaquin Valley than in the coastal areas. The study concluded that: "It is in the years when conditions are particularly conducive or repressive to mildew growth that this system can be of most value in helping to prevent severe disease outbreaks or to eliminate unnecessary treatments" (Sall et al. 1983).

This approach has an advantage over field monitoring in that it reduces the need for labor in the vineyard. Its disadvantage is that it cannot identify areas within the vineyard where mildew is most intense, nor can it account for temperature variations at different locations within the canopy. Monitoring disease incidence and fruit sugar level in vineyards should result in optimum management of powdery mildew, particularly where expensive systemic fungicides are used.

Botrytis Bunch Rot

There are more than 70 species of fungi that cause fruit rots in grapes, but most are secondary invaders, relying on other organisms to enable them to gain entry to the fruit.

Botrytis cinerea, which causes botrytis bunch rot, is second to powdery mildew as a primary pathogen of winegrapes. In most cases, this fungus is an undesirable element in the vineyard, but under proper climatic conditions it is left to infect the fruit, resulting in grapes of high sugar and increased glycerine content, which are processed into highly aromatic, naturally sweet wines (Winkler 1962). It has long been known as the "Noble Rot", since it results in choice and expensive wines. The Sauterne region of France, as well as parts of Germany, are particularly well known for these wines.

In Washington, 12 of 32 growers surveyed treat regularly for this disease, which was particularly troublesome in the 1982 harvest due largely to postponed harvest dates. Treatment is often necessary because heavy infestations cause excessive desiccation of the fruit, rotting of the berries, and reduced tonnage. Early season treatment with either systemic or contact fungicides around the time of bloom are recommended to help reduce the initial infection. First symptoms are microscopic and the established fungus is thought to remain dormant until later in the season when the berries begin to increase in sugar content. At this point, single berries turn brown and rot, producing visible spore masses or gray mold. Tight clustered varieties are particularly susceptible to rapid spread of this disease (Anon. 1983a).

The fungus overwinters as a sclerotium which is associated with mummified fruit from the previous season. Moist spring weather leads to spore production which is the inoculum thought to infect the stigmas of young grape flowers. Following the quiescent period, the fungus begins to grow, causing individual berries to rot and become covered with the gray mold, which is rich with spores. These spores can be carried by wind to infect healthy, mature berries. Disease development and spread is a function of fruit sugar levels, humidity, presence of free water on the fruit, and temperature. Ideal temperatures are from 58 to 82F, and RH greater than 90% is required for growth. Heavy damage is usually associated with pre-harvest rains which provide both the moisture and temperature needed for spread (Flaherty et al. 1982). This was the situation in parts of California during the 1982 harvest which resulted in substantial losses.

Botrytis cinerea is best controlled by an integrated strategy which considers crop management as well as effective chemical treatment. Removal of or discing under mummified fruit during the winter or early spring will reduce inoculum. If possible, overhead irrigation of grapes should not be practiced once the fruit is mature, but if irrigation is necessary, it should be done on a warm, windy day to shorten the drying time and minimize the amount of free water on the fruit clusters. Summer pruning of vines as well as alternative canopy management will improve air circulation and reduce fungal spread and damage (Anon. 1983a).

Systemic fungicides such as benomyl are applied at 1% bloom to prevent initial infection. A follow up spray may be necessary depending on the length of the bloom period. Contact fungicides such as captan or dichloran are applied at full bloom followed by two additional sprays to protect young berries (Flaherty _et al._ 1982, Anon. 1983a, Garren _et al._ 1982). Fungicides should not be used within one month of harvest because the survival of desirable yeasts may be threatened.

Of the 12 growers who reported treating botrytis rot in their vineyards, 10 used 1 to 3 applications of a benomyl and captan spray mixture; the other 2, whom I consider to be the most progressive managers that I have been exposed to, used three applications of vinclozolin (Ronilan), which is under experimental use permit.

Early season monitoring for this disease is of little use because a prophylactic spray is necessary to prevent the initial infection. Mid-season monitoring is important in order to estimate damage and identify areas where the disease is more intense. Certain varieties should be watched more closely than others. Choice of chemical is important as _B. cinerea_ has already shown resistance to benomyl in Washington and California. Either rotation of fungicides or mixtures may be advisable to extend the effectiveness of these chemicals.

Verticillium Wilt

Verticillium wilt, caused by the fungus *Verticillium dahliae* Kleb, is a widespread fungal disease affecting several plant species. It was first reported on grapes in Washington by Skotland in 1979, and is under intense scrutiny by Chateau Ste. Michelle now, due to its presence and ill effects on some vines at their Paterson vineyard, beginning in the 1980 growing season. Prior to this, the wilt was of minor importance in winegrapes, in which control measures are seldom implemented. The incidence of the disease increased at Paterson during the 1981 season causing further concern and the likelihood that a virulent strain may be present at this site compared with other production areas (Hirschfelt 1981b).

Symptoms associated with this disease are wilting of foliage in late spring and early summer, followed by death of the affected shoots. Vines infected in the early season fail to set fruit properly, and later infections can cause the berries to shrivel and dry. Upon inspection, there is a brown discoloration of vascular tissue. Xylem tissue can be blocked reducing upward movement of water to 2-4% of that found in a healthy plant.

The fungus overwinters in the soil as microsclerotia, which under proper conditions produce hyphae that infect intact or wounded roots. From here, the fungus migrates up the xylem reducing the upward movement of water and nutrients. Hirschfelt describes the situation in infected Ste. Michelle vineyards as follows: "Many fields have been infected from planting certified potato tubers and the inoculum level subsequently built up by potatoes and solanaceous weeds. However the disease has also been found in uncultivated areas, indicating that the fungus is native to some soils. It is suspected that Ste. Michelle's vineyard was infected by potato tubers from previous farming operations".

Hirschfelt indicated that this is a more serious pathogen than has been previously experienced in California and may require control measures. The best preventative strategy is to avoid planting vines on soils that are likely to harbor this fungus. Some knowledge of the former cropping history must be obtained before a site is considered for vineyard development. Sites that are prone to high levels of inoculum can be fumigated prior to planting. It is not known whether such a treatment is cost effective for this disease alone, or the length of protection that would be provided (Hirschfelt 1981b). Soil samples taken prior to planting should reveal the inoculum levels of the fungus. With this information, the producer is in a better position to make a decision regarding site choice and pre-plant treatment. The only post-plant treatment that may be effective is soil solarization. According to Hirschfelt (1981b), this treatment has effectively reduced disease incidence in California pistachio orchards. The soil is covered with a clear polyethylene tarp for several weeks during the summer. This increases soil temperature and reduces the amount of viable inoculum. More experience is needed in Washington with this disease and its management to determine whether such a treatment can be justified both practically and economically (Hirschfelt 1981b).

Eutypa Dieback

Eutypa dieback is a disease which generally affects older vineyards and is caused by the fungus, *Eutypa armeniacae*. This fungus has world-wide distribution, and the dieback associated with it in Washington vineyards is of important economic consequence. The greatest loss from this organism is the resulting shortened economic lifespan of the vineyard. In California, the incidence of the disease has increased in the last few years for two reasons: too little attention given to removal of infected vine parts, and too much use of sprinkler irrigation which creates a moist environment favorable to the fungus (Flaherty *et al.* 1982).

Symptoms of dieback are best seen in the spring when the shoots are 10 to 15 inches long. Infected vines show individually weak and stunted shoots with shortened internodes. Leaves of infected shoots appear chlorotic, misshapen, and distorted, and later take on a tattered appearance. Berries on infected shoots usually fail to mature. Over a period of a few years, if the infected portion of the vine is not identified and removed, the entire arm or cordon may be killed. It is common with this disease for one side of the vine to be dead while the other appears perfectly healthy. Vineyards that are ten years or more in age are most susceptible to infection. The diagnostic symptom of the disease is the formation of pruning wound cankers, which are visible when a small portion of bark near the pruning cut is removed (Flaherty et al. 1982).

Initial infection occurs through pruning wounds, as spores come in contact with freshly cut wood. Infection is increased during wet periods such as rainstorms. The spores germinate and the fungus grows into the wood, producing a canker which will girdle and kill the vine arm in 5 to 10 years. Perithecia may develop in dead wood and are the only known sources of spores which can infect new wounds during or soon after rainfall. Spores from perithecia may be discharged for as long as 5 years (Flaherty et al. 1982).

Losses may be reduced by identifying the disease through the observation of spring symptoms, followed by the removal of the entire diseased portion of the vine. Upon examination, the cross section of diseased wood will show a discoloration of dead wood in the shape of a segment of pie. The absence of this discoloration indicates healthy tissue. It is important to cut back to healthy tissue, removing all infected wood. Dead, infected wood should be removed from the vineyard. Pruning should be conducted in dry weather, and fresh wounds should be dressed with a protectant fungicide paint such as benomyl (Anon.

1983a).

Crown Gall

Crown gall, also referred to as black knot, is a disease affecting many woody and herbaceous plants including grapes. It is caused by a bacterium, *Agrobacterium tumefaciens* Smith and Townsend, which is ever-present in the soil and very widely distributed. An open wound caused by mechanical injury or frost cracking allows this agent to gain entrance to the vine and form a gall (Flaherty *et al.* 1982). The galls are usually found close to the soil surface, but secondary galls can form higher up on the vine. Upon the entrance of the bacteria, which are often splashed up from exposed soil, uncontrolled xylem cell division occurs, resulting in tissue that does not conduct water efficiently. The tumors usually dry up after destroying local vascular tissue and then slough off. In some cases, water and nutrient transport may be reduced to 20% of that found in healthy tissue. In some cases, the yield can be decreased, or the whole plant may die. Recently infected plants can be identified by the presence of an orange or cream-colored gall close to the ground. Even when the gall dries up or is removed, uncontrolled and disorganized cellular growth may continue in the plant in the absence of the bacteria (Agrios 1969).

The best control strategies are prevention and sanitation. Pruning tools that contact galls can spread the bacteria, so it is advisable not to cut into galls. Avoiding contact with trunks when cultivating will minimize mechanical injury, and so reduce the infection courts for the pathogen. Nursery stock should be disease-free and any plants that have galls must be discarded. Fumigation of infested soil has not proved to be useful. Until recently, this disease has not been a problem in California. However, with an increase in nursery stock grown under mist, and an increase in the use of sprinkler and drip irrigation, it is becoming more important (Flaherty et al. 1982). Special attention should be given to varieties that are known to be susceptible to winter damage. Varieties which through experience in Washington tend to lack winter hardiness include: Sauvignon Blanc, Semillon, Cabernet Sauvignon, and Grenache (Clore 1982).

Of 32 growers surveyed, only one reported treating vines infected with crown gall. However, several other growers expressed concern over its presence. This disease may become more economically important in Washington than in California because of the colder winter climate and the greater amount of winter injury that results, as well as the invariable practice of irrigation which is necessary in most Washington grape growing regions.

Table III lists disease pests as reported by vinifera growers surveyed in Washington.

Table III Disease pests reported by vinifera growers surveyed in Washington.[a]

Common name	Latin names	# Growers reporting as problem
Powdery mildew	*Uncinula necator*	31
Botrytis bunch rot	*Botrytis cinerea*	12
Crown gall	*Agrobacterium tumefaciens*	1
Verticillium wilt	*Verticillium dahliae*	1

a Based on response to question #11 in questionnaire.

Viruses

There are three virus diseases of main concern to the California winegrape industry. These are leafroll, fanleaf, and corky bark. Each is identified by symptoms on the foliage of affected plants, and all are widely distributed throughout the world. They are transmitted primarily by man through propagation of plant material. None is known to be transmitted by insects, but one, fanleaf, can be transmitted from root to root by the dagger nematode, *Xiphenema index* Thorne and Allen (Flaherty *et al.* 1982). Effects of viruses on grapevines include: yield loss, reduced plant vigor, shortened economic lifespan of the vineyard, and extension of the normal harvest date. On a nationwide basis, viruses account for 75% of the losses suffered in grapes (Agrios 1969).

Virus diseases of concern in Washington, include leafroll, fanleaf, and tomato ringspot (Ahmedullah 1980). Leafroll is very widespread and is considered one of the most important contributors to production losses worldwide (Flaherty *et al.* 1982). Yields can be reduced 20%, and fruit maturity can be delayed for up to one month (Flaherty *et al.* 1982), thus increasing the risk of fruit rot and bird damage.

Fanleaf can be found in most vinifera plantings of non-certified stock. Although it can be spread by dagger nematodes, the species responsible for its transmission, *Xiphinema index*, does not predominate in Washington vineyards, but it may occur (Ahmedullah *et al.* 1980). When a diseased plant is removed, the diseased roots and the nematode vector remain in the soil and can re-infest any plant placed in the area for up to six years. Once a vineyard is infested with this pest complex, replanting with vines should be avoided for from six to ten years. Soil fumigation with a nematicide can shorten the replant interval, but the effectiveness of this treatment depends on the type of soil and is very expensive (Flaherty *et al.* 1982).

Tomato ringspot virus can produce a general decline in vinifera plantings and can produce a range of leaf symptoms depending on the variety affected. Leafroll, fanleaf, and tomato ringspot are all sap-transmissible, which allows rapid identification of disease in suspect plantings. Sap from infected grape plants produces leaf symptoms on leaves of the herbaceous indicator *Chenopodium quinoa* Willd., which can be analyzed to identify the virus.

Realizing the long term effects that viruses can cause in vineyards, there is only one logical strategy for control in Washington, and that is prevention through implementation of a certified grapevine program. The source of certified stock planted in a new vineyard in Washington can be traced either to the foundation block, maintained and operated by W.S.U. at Prosser, or to other states or Canada, which can document the production of the stock under a similar certification program.

The foundation block at Prosser is made up of plants that were propagated from virus-free cuttings supplied either by the University of California or the Sidney Research Station on Vancouver Island in British Columbia, operated by Agriculture Canada.

Cuttings from the Prosser foundation block are indexed with indicator varieties, most commonly "LN 33", a V. rupestris cultivar, and are determined to be virus-free before their parent material can be used as stock to establish a mother block. The indexing process is rapid, performed under controlled laboratory conditions, and completed within two months (Mink and Parsons 1977). The mother blocks are maintained by nurserymen and these provide propagating wood for nurseries which supply local planting stock. This stock is certified to be free of virus and true to name. Foundation and mother blocks are inspected twice during each growing season for visual symptoms of virus disease. Nursery stock is also inspected twice during each growing season for virus symptoms, and also at digging and grading to insure freedom from rootknot nematodes, crown gall, and other visible diseases (Anon. 1978).

Any imported cuttings must be indexed prior to inclusion in the certified program. Minimum index requirements include mechanical inoculation on lambsquarters and graft inoculation on the V. rupestris cultivars: "St. George", "Baco 22A", "LN 33", as well as Pinot Noir. This process takes from 1 to 2 years to complete depending on the methods used (Mink).

At present, viruses are not considered major pests in Washington vineyards, largely due to the effective certification program and laws which prohibit importing uncertified plant material.

The B.C. Grape Production Guide 1983 (Anon. 1983b) stresses the importance of preventing the introduction of viruses into the Okanagan Valley because of the long term threat that they pose to the industry. Virus diseases have been detected on incoming grape propagating material through monitoring by the Plant Quarantine Division of Agriculture Canada. Prevention is the best policy in any new grape producing area and is best accomplished by careful screening of planting material.

Weeds-Vegetation Management

Strategies for weed control depend on several factors and it is therefore unrealistic to assume that one approach will be suitable in all situations. Some of the factors that determine the strategy used include: vineyard age, irrigation method, soil type, topography, weed species present, and cultural methods preferred by individual growers. Traditionally, weed control in vineyards was attempted by repeated cultivation both under the vines and between the rows throughout the growing season. The current trend is a heavy reliance on herbicides, particularly for use under the vines. This trend results from the high cost of repeated cultivation by discing, and the availability of cost-effective, pre-emergent, soil-applied and post-emergent foliar-applied herbicides.

Of 32 growers surveyed in Washington, 24 use herbicides regularly, and 19 of these use a combination of residual pre-emergent and contact foliar-applied chemicals. Of 8 growers who do not use herbicides, 7 operate small farms of less than 25 acres. Weeds are considered one of the most persistent types of pests by 13 growers, and chemical weed control costs averaged about 40% of total pesticide costs for all 32 respondents.

Undesirable vegetation not only has a direct effect on the availability of nutrients and water to the vine, but it may also relate to the entire pest complex. There are specific weeds which are hosts to, or make up suitable habitat for, certain insects, nematodes, diseases, and vertebrate pests. Knowledge of these associations is important in identifying and managing weeds in the vineyard. Other effects of weedy growth include increased humidity in the vineyard, which can affect the spread of fungal diseases, decreased temperature, which can increase the chance of frost damage in early spring, and annoyance to harvesters if the weeds are uncontrolled.

Weedy growth, or natural vegetation also have advantages when compared with clean cultivation. Where vegetation is present, the insect complex is almost certainly diverse, allowing for a full complement of beneficial species and possibly effective natural control (Altieri 1983, Tedders 1983, Altieri and Whitcomb 1979). An interesting strategy that needs further research is the manipulation of certain weeds to increase the effectiveness of beneficial insects. Weeds can provide alternative food sources for beneficial insects, reduce crop apparency, and improve sycnhronization between pests and their natural enemies (Altieri and Whitcomb 1979). Some flowering weeds can supply pollen and nectar to parasitoids and predators which can help increase their reproductive capacity or longevity. Weeds may also allow adult parasitoids to bridge a critical period when the host is not available. In 1967, Leius compared parasitism of codling moth and tent caterpillar in orchards with varying amounts of flowering weeds present. In those orchards where flowering weeds were present, parasitism in tent caterpillars was 18 times greater than in orchards lacking such weeds. His study in Belleville, Ontario, illustrated a principle of potentially wide application, rather than a solution to a particular orchard pest problem. Application of this strategy was limited because of high pesticide use in the orchards. Increased parasitism through association with certain weeds has been observed in wheat, cabbage, and orchards (Altieri and Whitcomb 1979). Much work has been done in Russia with altered cover crops aimed at improving parasitoid effectiveness. The successful introduction and establishment of some parasites, as well as annual releases can be dependent on the presence of certain weeds which may be the only source of essential food requirements of the beneficial insects (Altieri and Whitcomb 1979).

As well as supplying nectar and pollen for direct use by beneficials, weeds can increase herbaceous, non-pestiferous insect populations, which serve as alternative prey for entomophagous insects. This can improve the effectiveness of the predator in controlling the target pest. Cattail pollen, applied in vineyards in California, increased the abundance of non-pest tyiid mites, which are an important alternative source of prey for the predaceous mite, M. occidentalis. This allowed M. occidentalis to survive periods of low abundance of the target pest, the willamette mite, Eotetranychus willametti McGregor (Hagen 1976). Where Johnson grass was allowed to grow in vineyards in California, there was a buildup of alternative prey mites which supported populations of the same predator mite, and restrained the pacific mite, Tetranychus pacificus to non-economic numbers (Altieri and Whitcomb 1979).

Normally, beneficials move from weeds to crops but in some cases, the prey found on weeds may forestall this dispersal. Proper weed management, such as timely mowing, can force dispersal of the beneficials to crops where pests can be controlled.

The use of weeds to improve the effects of beneficials is limited largely by the complexities involved in attaining the desired weed complex, once the desirable weed complex has been determined through extensive field studies. Factors that control the mix of weeds include the availability of soil nutrients, soil pH, herbicide use patterns, and the timing of cultivation.

Weed seeds can be sown directly, but results are inconsistent because seeds of the various species tend to have special requirements for germination. In order to use weeds to enhance beneficials, economic thresholds of weed populations need to be defined to avoid competition with the crop. In general, there is a lack of information on ways to encourage the presence of certain weed species within a crop for the purpose of increasing entomophagous insect populations (Altieri and Whitcomb 1979). Before considering manipulation of weeds as a measure to increase natural controls in Washington vineyards, a better understanding of the insect-weed-crop complex is needed. Although vegetation management has definite pest management implications in tree fruit orchards, there has been no research in Washington aimed at comparing insect diversity in clean cultivated versus permanently cover cropped vineyards. I think that a well managed permanent cover between vines, and herbicide use in the vine rows is the optimum vegetation scheme where irrigation systems and soil type allow.

Weed control is most important in non-bearing vineyards and particularly in the first year, when competition from weeds can reduce the growth of the vines by 50%. Reduced growth means that second year vineyards may have to be managed as though they are still in their first year. This increases the investment of both time and money before the vineyard reaches bearing age. Uncontrolled weed growth can also harbor vertebrate pests such as pocket gophers and field mice, making their detection difficult and increasing the risk of damage. Young vines are intolerant of herbicides, and owing to a shallow root system are more easily damaged by mechanical cultivation than are older vines. For these reasons, weed control must begin before the new vineyard is planted (Flaherty et al. 1982).

Repeated cultivation prior to vineyard establishment will weaken perennial weeds such as field bindweed and Canada thistle. This treatment can be followed by smother crops such as millet, sorghum, sudangrass, or alfalfa. Alfalfa is recommended because of the nitrogen that it will provide to the new vineyard once it is plowed under (Ahmedullah 1982). An important weed control measure prior to planting the vines is a sub-surface layering of trifluralin about 4 to 6 inches below the soil surface. This is a pre-emergent residual herbicide which will kill many germinating weeds as the new growth contacts this herbicide zone. The entire vineyard can be treated or just the vine rows, depending on weed population and the vegetation management plan to be practiced. Some weeds such as mustards, nightshades, and thistles are tolerant of this treatment and will require treatment with a contact herbicide before they become well established. To avoid injury, the roots of the vines must be well below the trifluralin treated zone when the vines are planted. Fumigation prior to planting, using methyl bromide and chloropicrin (Pintofume) aimed at nematode control, will also give some insect and weed control. Trifluralin can also be incorporated into the top 2 to 4 inches of soil by discing, but areas where a cover crop is to be established should not receive this treatment (Flaherty et al. 1982).

Once the vineyard is planted, weed control measures should be taken regularly. Weeds under the vines are controlled by chemical or cultural practices or a combination of the two. A common practice now is to keep a weed-free strip under the vines by using residual herbicides in either the spring or fall, plus contact herbicides as needed, or in some cases mechanical hoeing. The choice of herbicides is dependent mainly on the age of the vineyard, type of soil, method of irrigation, and weed species present. The Washington spray guide (Anon. 1983a) covers herbicides that are presently registered for vineyards and recommends them, based on these factors. Often a combination of an appropriate residual herbicide such as oryzalin (Surflan) and a contact such as paraquat will provide knockdown of existing weeds and residual control of later germinating plants. Great care must be taken with foliar herbicides to avoid contact with the vines, especially in young vineyards,in which the vine trunk tissue is more sensitive and less woody than older plants (Parker 1981).

Simazine and diuron have been the most commonly used residuals, but they are being replaced by a newer group of herbicides which are safe on a broader range of soil types, not so wide in the spectrum of weeds controlled, and with more exacting requirements for application, such as soil incorporation by timely cultivation or watering. Their advantages lie in reduced risk of damage to the vines, particularly on sandy soils, compared with simazine and diuron. Examples of these new herbicides are trifluralin (Treflan), which must be mechanically incorporated into the soil to be effective, and oryzalin (Surflan) and napropamide (Devrinol) which are registered for use on new and established vineyards and must be watered in after being applied to bare soil (Parker 1981). The persistence of these herbicides ranges from a few months to a year or more. Degradation occurs faster if the soils are wetted frequently as with drip irrigation. Generally, residual herbicides are strongly adsorbed to soil particles and do not leach readily. In sandy soils, leaching is more rapid, and hence damage is more likely, and persistence is shortened when compared with soils that are high in organic matter (Flaherty et al. 1982).

Weed control between the rows is largely dependent on the type of irrigation. If a permanent cover can be maintained, it is usually an effective weed control measure, because the desired cover competes strongly with invader weeds. Other benefits include better water penetration, addition of humus to the soil, protection against wind erosion, and higher humidity and less dust (Flaherty et al. 1982). The cover crop must be maintained as a vigorous and dense stand if it is to remain competitive with invading weeds. This is accomplished through repeated mowing during the growing season, adequate water, and the addition of nitrogen between the rows. Although there has been no local research to support it, I judge that maintaining a permanent, desirable vegetative cover between the rows will help beneficial insect survival by supplying more protective cover than would be found in a clean cultivated vineyard.

In Washington, because of the cold winters, growers are encouraged to plant an annual cover crop which competes with the vines in the fall, and slows their vegetative growth. This results in proper hardening of the vines before freezing winter temperatures. If a permanent cover is used, seasonal planting, which involves soil preparation and seeding, is not necessary. Prior to planting the seasonal cover crop, weeds are controlled between the rows by regular discing beginning in the early spring. This is a common practice in furrow-irrigated vineyards. Spring cultivation incorporates winter vegetation into the soil, protects against frost by increasing the reflected heat in the vineyard, and conserves water held in the winter weeds which otherwise would be lost through evapo-transpiration.

In addition to seeded cover crops, some growers allow the existing weeds to grow between rows, mowing them as they would a permanent cover crop. It is important with this practice to monitor particular weeds such as bindweed and bermudagrass, which may become very troublesome if they begin to dominate the stand (Flaherty et al. 1982). In one vineyard which I observed in the Columbia gorge area, weeds had been allowed to grow apparently beyond control. Here, cutworm damage was widespread on the vines in early spring, and moisture loss to the weeds was probably very high. Some growers have found that after cleaning up weeds, chemical control for cutworms is no longer necessary (Little 1980). The benefits of a controlled cover of existing weeds are similar to those experienced with the use of a planted cover such as red fescue, but it is more difficult to maintain as dense and desirable a stand (Ahmedullah 1982).

The choice of a weed control strategy is often limited by the method of irrigation. With overhead sprinkler, pivot, and drip irrigation, a perennial cover of grass between the vine rows can most probably be maintained. With the drip system, the limiting factor is the type of soil. In the Wahluke Slope area, recent trials designed by Tom Thorsen of Weinbau Vineyards have been encouraging for cover cropping under drip systems. Availability of water between the rows is the critical factor for cover crop survival. Lateral movement of water in the soil can be increased with fine-tuned controls in the irrigation period and a good knowledge of the soil texture and its effect on water holding capacity. Maintaining an established cover under drip through the summer is easier than establishing a new cover at this time because of the extreme heat in the area. Thorsen has had good results with wheat planted in July on heavy silt loam soils using a slow-pulse irrigation frequency (Anon. 1983c). Under drip irrigation, the weeds tend to concentrate under the vines, and herbicide use becomes complicated in a constantly wet soil. In this situation, the use of residuals may not be so effective because of the shorter persistence and increased risk to the vine. In sandy soils under drip irrigation, foliar herbicides may be more useful. Where irrigation is not necessary, clean cultivation is practiced to reduce soil moisture loss and to control weeds.

Growers surveyed in Washington were asked to list their problem weed species. Of the 32 growers, 15 listed Canada thistle and 15 field bindweed. These were followed by quackgrass (12), mustards (8), Russian thistle (5), puncturevine (4), field sandbur (4), redroot pigweed (4), cheatgrass (3), and marestail or Canada fleabane (2). Of 29 growers who considered that they had weed problems, 24 used glyphosate as a spot treatment. In addition to these weeds, perennials such as yellow nutsedge, and bermudagrass may result in poor stands during the establishment years (Parker 1981).

Accurate identification of weed species is important in order to make a sensible choice of herbicide, as well as to minimize weed-pest associations. Control of mustard spp. over the long term should reduce the pest status of cutworms, because these weeds are favored oviposition and protection sites for this insect. Solanaceous weeds should be eliminated because they may harbor verticillium wilt, and their presence may be the source of inoculum for this disease in a vineyard. Weeds can attract birds in the early fall, increasing the potential for fruit damage by these pests as the season progresses. The choice of a cover crop is important because certain covers may influence nematodes. Cone has observed that black vine weevil populations were larger in vineyards with red fescue cover crops. Since this is the most commonly used permanent cover, the situation should be monitored. Red fescue is desirable because it is hardy, easy to establish, and is a good weed competitor (Ahmedullah 1982).

Weeds as pests do not often get much attention because their effect on crops is more subtle than highly visible disease and insect pests (VandenBorn 1982). Effective weed management can not only increase overall productivity in a vineyard by reducing direct competition between weeds and vines, but may also reduce other pest organisms which are partially dependent on some weeds for their survival. "The fact that weeds are ever-present within and around crop fields, makes them an important agro-ecosystem component, which can be manipulated to manage pests and their natural enemies" (Altieri and Whitcomb 1979).

On the following page is a list of problem weeds as reported by survey respondents (Table IV).

Table IV Weed Pests Reported by Vinifera Growers Surveyed in Washington.[a]

Common Name	Latin Name	# Growers Reporting as Problem
Annuals		
Mustards	Brassica spp	8
Russian Thistle	Salsola kali	5
Puncturevine	Tribulus terrestris	4
Field Sandbur	Cenchrus incertus	4
Redroot Pigweed	Amaranthus retroflexus	4
Cheat Grass	Bromus secalinus	3
Marestail	Conyza canadensis	2
Perennials		
Canada Thistle	Cirsium arvense	15
Field Bindweed	Convolvulus arvensis	15
Quackgrass	Agropyron repens	12

a Based on response to question #15 in questionnaire.

Nematodes

Trials conducted by W.S.U. on Concord vineyards in Washington report the presence of at least four predominant nematode species in various sites. These are: Meloidogyne hapla Chitwood (northern root knot), Xiphinema pachtaicum (dagger nematode), Criconemella xenoplax (ring nematode), and Paratylenchus spp. (pin nematodes). The researchers found that: yearly application of aldicarb and carbofuran may not be necessary to maintain desirable yields; nematodes are more of a problem on sandy loam than on loam soils; incorporation of non-fumigant nematicide into the soil is best achieved under sprinkler irrigation; aldicarb has been the most consistent nematicide in increasing yields (Santo, Ponti, and Wilson 1982). However, at present there are no nematicides registered for use in established grape vineyards and less than 10% of the total wine grape acreage has been sampled for nematode presence (Santo pers. comm. 1983). Pre-plant treatment with nematicides is not a common practice at present, even though it is the only option available to growers. This is probably a response to the cost of fumigation which can be as high as $1000/acre (Emanuels 1982), a low level of concern among producers regarding nematodes, and the absence of established economic thresholds.

Although 30 of 32 growers surveyed were aware that nematodes can reduce yield and in some cases transmit viruses, only 6 had sampled any portion of their acreage.

The situation is worsened by an incomplete understanding of the quantitative impact of nematodes on grapes. Several questions on economic threshold levels and the importance of each species remain unanswered (McKenry and Ferris 1978). As nematode sampling increases in Washington vineyards, growers and pest managers will be able to make better management decisions regarding these potential pests.

The endoparasitic nematode *M. hapla* causes damage when second stage juveniles penetrate the roots just behind the growing tip where they establish themselves in the conducting tissue. Galls are formed in the roots, disrupting water conduction. The infectious juveniles are from two to five times more numerous in the fall and winter than in spring and summer (Flaherty *et al.* 1982). Therefore, when attempting to measure relative population size, the time of sampling must be considered in order to make accurate comparisons between sites. Root knot nematodes are most commonly found between 6 and 36 inches beneath the vine row. They are best adapted to coarse textured soils and have a wide plant host range (Winkler 1962).

X. pachtaicum is an ecto-parasite, closely related to *X. index* which is known for its association with fanleaf virus, and *X. americanum* which vectors yellow vein virus and tomato ringspot (Stace-Smith 1977). As with *M. hapla*, populations are highest during the winter months. The nematode feeds near the root tip, where it may cause enlargements, but this symptom is not always present, for which reason, direct sampling must be done to confirm its presence (Flaherty et al. 1982).

C. xenoplax is also an ecto-parasite, occurring in a wide range of soil types. Extensive root pruning results from feeding by this nematode and as with all plant parasitic nematodes there are no diagnostic foliar symptoms. Based on yield improvement following nematicide treatments in California, this nematode deserves more research attention (Flaherty et al. 1982).

The pin nematodes are the smallest of the plant parasitic nematodes, and even though they can build to high populations, research has not shown any reduction in yield or quality of grapes associated with them (Flaherty et al. 1982).

Initial damage by nematodes is to the roots, which when infested are less efficient in delivering water and nutrients to the vine. The above-ground symptoms associated with root damage can be easily confused with those of nutrient deficiencies, since the leaves may appear yellow and wilted, and the yield and quality of fruit may also be reduced. In addition to physical root injury and its consequences, the resulting biochemical interactions impair the overall physiology of the vine, making it more susceptible to other pathogens. Nematodes have been associated with several fungal diseases, including verticillium wilt. Such etiological complexes can result in combined damage which is considerably greater than the sum of the damage caused by each pathogen acting alone (Agrios 1969). More common is the association between certain genera of nematodes, especially

Xiphinema, and viruses. Among the viruses transmitted by nematodes are fanleaf and tomato ringspot (Agrios 1969).

Because specific nematodes cannot be identified from the above-ground symptoms, sampling must be done to confirm nematode presence, population size and species composition. Flaherty *et al.* (1982) have developed monitoring guidelines for pre-plant and established vineyards in California. Samples should contain material from as deep as three feet, particularly from sites that have had a perennial crop in the previous five years. In established vineyards, samples are taken from the berm area, 12 in. to 18 in. from the vine trunk to a depth of about 30 in.. Roots must be included in these samples, which should be taken within a week of rainfall or irrigation when the soil is relatively moist. Nematode sampling and diagnosis are very complex and results can vary depending on the number of samples examined, and most importantly, on the method of extraction used by the diagnostic laboratory. Extraction methods should be chosen based on the species suspected to be present. Once the relative population density and species composition are known, several factors must be considered in order to relate this to damage or damage potential. Soil texture, root depth, irrigation method, observable soil problems, grape variety, vineyard situation, and sampling date must be considered. Only when all these factors are considered can sound recommendations be made. It is important to realize that a direct correlation between nematode numbers and plant damage should not be expected.

The control tactic most often practiced in grapes is soil fumigation, prior to planting the vines. There are several fumigants available and the effectiveness of each is related to the degree of soil preparation prior to application. Before planting a new vineyard in a nematode infested area, the ground should be cleared and then chisel-plowed several times. This should be followed by an annual grain crop which is harvested during the summer or early fall. Following harvest, the ground should be chisel-plowed to a 2 ft. depth, which is followed by fumigation, usually in the late summer or early fall. The new vines should be planted in the late winter or early spring (Flaherty <u>et al.</u> 1982). This preparation requires considerable time, planning and especially expense. As this is the only chemical control strategy available to growers at present, it should certainly be considered in obviously high-risk sites.

Rootstock trials for nematode and phylloxera resistance were started in two places in Washington in 1980 and 1981, and the results are expected by 1986 (Ahmedullah, pers. comm. 1983).

Until there are nematicides registered for use in established vineyards, growers must rely on preventative cultural practices. Manure has been used to improve the vigor of vines in the presence of nematodes, although it probably has no direct action against them. Any practice which enhances root growth and nutrient uptake will minimize the impact of nematodes. The choice of cover crop used and selective weed control should be based on knowledge of nematode species present. Although it is known that certain cover crops tend to increase nematode populations, little research information is available. Nematodes can be spread mechanically by machinery, and it is important to minimize spread from infested to clean sites. At present there are no biological control agents known that could be incorporated into a nematode control plan (Flaherty *et al.* 1982).

Recommendations for nematode control in California, where most of the data have been collected, are based on sampling to measure species composition and relative population size, combined with knowledge of the specific vineyard characteristics mentioned above. With continued research and increased grower awareness of nematodes as pests in Washington, more acreage should be sampled in the future, and pest managers will be better equipped to make sound recommendations.

Vertebrate Pests

Birds have always been pests of agricultural crops, but the situation has worsened in the past fifty years. This is due largely to increasing crop acreage which supports an increasing population of damaging bird species. The starling, *Sturnus vulgaris* L., has been a problem species in California only since 1962, but is now considered a hazard to many wine grape producers (Boudreau 1972). Of 32 growers surveyed in Washington, 29 reported that it was necessary to use some measure to control birds. Robins were reported as a major problem species by 29 growers, followed by starlings, considered a pest by 21 respondents, and magpies which were reported by 5 growers. Other pest species reported by fewer growers were; pheasants, red-shafted flickers, sparrows, blackbirds, finches, and woodpeckers. Most growers use a combination of control tactics to reduce damage, but at present, the use of Mesurol, a chemical repellent sprayed on the crop, is the favored tactic, used by 24 producers. This choice is followed by shooting to kill (19), exploders (19), and electronic noisemakers (8). Six growers have tried trapping, 4 have tried raptor models, 3 have used scarecrows, 2 have used flagging tape, and 2 have used bio-sonic distress calls. Mesurol, now available under temporary use permit, is recommended by the Cooperative Extension Service as the most effective bird control tactic. This repellent is effective against both robins and starlings, and even in vineyards where damage is somewhat predictable, growers report losses of less than 5% of the expected yield if it is used. As with most assessments of vertebrate pest damage, these estimates of loss are not based on regular scientific measurements in the field. Although 19 of 32 growers attempt to control birds by shooting, it is generally known that this is one of the most ineffective strategies. Exploding devices, used by 19 growers, are effective against starlings if not over-used, but generally do not frighten robins. Only 2 growers reported losses as high as 10 to 20% in any one season.

In addition to birds, 14 respondents experienced damage from other vertebrate pests. Included were pocket gophers, reported by 6 people, followed by ground squirrels (4), rabbits (2), deer (2), and coyotes (1).

Northern Pocket Gopher

The northern pocket gopher, *Thomomys talpoides* Richardson, is a rodent. It can cause damage to vines by eating the roots, to which it gains access by an extensive underground system of tunnels. Damage is normally seen as a slow decline in the affected plant from the destruction of its roots. It is important not to confuse this potentially important pest with moles, which do not directly damage grape plants, are insectivores, and are confined to the west of the Cascade Mountains. The two are distinguished by the different shapes of the mounds which both form on the ground surface. That of the mole is volcano-shaped with a hole in the middle. The gopher mound is flatter and in the shape of a horseshoe (DeCalesta 1982).

Pocket gophers can be trapped effectively in small vineyards of less than 10 acres. Other options are poison baiting and gassing, which are more appropriate in large vineyards. Gopher controls should be carried out in the early spring before breeding begins (DeCalesta 1982). Control of pocket gophers is best accomplished by trapping and poisoning, according to Willis (1981). Gassing is generally not effective due to the extensive burrow system of this ground dweller (Willis 1981).

Trapping involves location of the main burrow which is usually 6 to 15 in. away from the mound. Once the burrow is located from the freshest mound, a trap should be set in each direction, and attached by wire or cord to a fastened marker above ground. The most successful trap is called a "Macabee" and is about 5 in. long. After setting the traps, mounds should be tramped down so that new gopher activity can be detected and further controls implemented where necessary (Willis 1981). According to Willis (1981), control of pocket gophers over large areas is best accomplished and most cost effective by using poison. After the main burrow is located with a probe, poison bait can be dropped down the probe hole. Grains coated with .25% to .5% strychnine have given good results. Milo and barley are preferred grains, however cracked corn, beans, oats, and wheat can all be effective (Willis 1981). Mortality checks should not be made until the bait has been exposed for two weeks. Control effectiveness can be checked by marking and opening a number of burrow systems in the treated area. If the burrows are still occupied, these openings will usually be closed within 48 hours (Anon. 1968).

Ground Squirrels

There are several species of ground squirrels which are found within the wine growing region of Washington east of the Cascades. The Townsend ground squirrel (Spermophilus townsendi Merriam), which is also known locally as a "sage rat", is probably the most commonly encountered species (Stream pers. comm. 1983). It is partial to the mixed grassland and sagebrush areas of south central Washington, and common throughout Yakima, Klickitat, and Benton counties in this habitat. These squirrels are highly gregarious and where large populations occur, the ground can be honeycombed with burrows (Kritzman 1977). They can easily become pests of alfalfa and grain fields as their preferred diet is green vegetation rather than seeds and fruit, the choice of most ground squirrels.

The Washington ground squirrel (S. washingtoni Howell) shares part of the Townsend's range, particularly in Benton county, but its range extends further east to the Washington-Idaho border. The Columbian ground squirrel (S. columbianus Ord) referred to as "go downs" in eastern Washington, is another dryland grass species present, but it prefers a rocky habitat to open areas, and is often seen in these locations along with yellow-bellied marmots (Stream pers. comm. 1983). However this squirrel is most common in the far eastern part of the state and along the Washington-British Columbia border rather than in the Yakima valley (Kritzman

1977). The California or Beechey ground squirrel (S. beecheyi Richardson) has recently extended its range from the south, crossing the Columbia river in about 1912. It is now found as far north as Naches, which is above Yakima. This is the largest ground squirrel in the area, measuring about 18 in. long with a very bushy tail and a mottled back. It occupies several vegetative habitats, the only criterion for successful establishment being relatively mild weather (Kritzman 1977). It perhaps does the greatest agricultural damage of any mammal in the Pacific states in grain fields and has caused high losses in almond orchards in the Sacramento valley of California by stockpiling almonds (Ingles 1965).

All of these ground squirrels are diurnal, and construct extensive burrow systems in which they seek cover. All except the California ground squirrel are known to hibernate within these burrows for 7 to 8 months of the year, during the fall and winter. Breeding takes place in the spring and the single litter produced each year can range in size from 5 to 11 young. Unlike the pocket gopher, the burrow system of this rodent has an open entrance with a fan of trails radiating from it. Ground squirrels often stand upright at the burrow entrance. This habit allows them to be easily recognized and identified and if considered damaging by the vineyard manager, also makes them easy targets for a .22 calibre rifle. A Conibear 110 trap baited with bacon and located over the burrow entrance is also an effective means of control (DeCalesta 1982). Control efforts must be carried out in the spring and early summer when ground squirrels are active. Scattering baits around the burrow entrance 10 to 14 days after the first appearance of squirrels is recommended and will suit large vineyards. Trapping, shooting, and gassing are effective if the infestation is confined to a small area (Anderson 1980).

Poor vegetation conditions generally provide a desirable habitat because of decreased plant density and possibly a greater variety of weeds (Anon. 1968). Weeds and grass seeds, stems and leaves of such plants as mustards, mallow, plantain, and alfalfa form its diet (Whitaker 1980). Maintenance of a uniform cover crop and good weed control under the vines may minimize infestations by this ground dweller. The squirrels may nibble on bark or eat the grapes, but they usually cause little damage; rather it is their presence that causes concern. The coyote, a natural predator, may be drawn into a vineyard where squirrels are present. Damage results when this predator digs at the burrow entrance, expanding the hole which leads to diversion of irrigation water, particularly where furrow irrigation is used (Hirschfelt, pers. comm. 1983).

Rabbits and Hares

Rabbits cause damage by girdling the bark from the base of the vine to as high as 1 ft. or eating the foliage of young grape plants. Rabbit damage can be differentiated from vole or gopher damage by the larger teeth marks. Their presence however, is usually indicated by seeing the animal, rather than through association with signs of damage (DeCalesta 1982).

According to Whitaker (1980) and Burt (1976), the only true rabbits native to Washington east of the Cascade mountains are Nuttall's cottontail (*Sylvilagus nuttalli* Bachman), which is well distributed and the Pygmy rabbit (*Sylvilagus idahoensis* Merriam), which is found among the sagebrush and confined to the southeastern part of the state including the Tri-cities. The Eastern cottontail (*S. floridanus* Allen), after several introductions, has flourished in eastern Washington and is reported to be present in agricultural areas such as the Horse Heaven Hills, where the sagebrush has been removed (Stream pers. comm. 1983). This rabbit is very similar to the native Nuttall's cottontail, but it is somewhat darker, though they are often confused (Kritzman 1977). There are three species of hares in this area according to Whitaker (1980). They are: the snowshoe hare (*Lepus americanus* Erxleben), the white-tailed jackrabbit (*L. townsendii* Bachman), and the black-tailed jackrabbit (*L. californicus* Merriam). Due to their greater size and abundance, hares are usually more destructive of agricultural crops than are rabbits.

Chemical repellents painted on the trunk to a height of 18 in. are effective, but expensive, and for this reason they are usually limited to use in small plantings or on outside rows (Johnson 1964). In large vineyards, particularly those bordered by rangeland, the most effective tactic is a poison baiting program. Bait should be placed in prepared stations located 100 ft. apart in damaged areas. These stations should be checked weekly to be re-baited and to remove any dead hares (DeCalesta 1982). The small number of growers reporting rabbits as pests in Washington vineyards suggests that they are considered a minor problem by most. Control efforts, where necessary, should be tailored to suit the specific conditions (Johnson 1964).

Deer

The white-tailed deer, Odocoileus virginianus Bailey, and the mule deer, O. hemionus Rafinesque, are the most abundant big game species in the United States and they are also the most important wildlife species in terms of crop damage (Strickland 1976). Deer were reported to cause crop damage in 40 states in the U.S. in a survey sent to state game agencies in 1957 (McDowell and Pillsbury 1959). Most damage by deer occurs in orchards, followed by grain fields, forage crops, and tree seedlings in descending order of importance (Strickland 1976). Although vineyards are damaged by deer, they are not highly favored sites for feeding at the present time, as evidenced by survey results in Washington, in which only 2 of 32 growers reported them as pests.

Both of the species mentioned inhabit the wine grape growing region (Whitaker 1980), though mule deer, native to dry grassland and sagebrush habitat pose a greater threat in most vineyard locations (Stream pers. comm. 1983). Deer are found in a wide range of habitats. The mule deer prefer forest edges, mountains, and foothills, and white-tailed deer are more common in farmlands, brushy areas, and woods. White-tail are not a problem in the Yakima valley, but may be a threat in the Paterson area along the Columbia river and also in the wooded Bingen area (Stream pers. comm. 1983). Both are primarily nocturnal, though they may be observed feeding during the day. Most of the damage to crops occurs at night. Familiarity with tracks and type of damage will help in identifying damage from deer. In a study of mule deer feeding habits in Montana, Wilkins (1957) found seasonal changes in the types of plants that were consumed. During the summer, 75% of the diet was supplied by forbs, with salsify and alfalfa being preferred. There was a shift during the fall and winter when the bulk of the diet was the browse plants; big sagebrush, bitterbrush, Rocky Mountain juniper, and western snowberry. Forbs and grasses were preferred in the spring. Also of interest in this study is the fact that 90% of the deer observed were occupying south facing exposures, which also is the desirable exposure for vineyards.

Deer can damage grape plants by stripping bark from the vine trunks, which is accomplished by biting the bark at the base of the plant and then ripping up towards the top. They will also eat leaves and small maturing grapes. A typical sign of this damage is the ragged edge of the leaf or the stem supporting the grapes (DeCalesta 1982).

Deer are protected in Washington, and therefore a permit is required to kill marauding individuals. Deer and elk are the only wildlife whose damage to agricultural crops is reimbursed to the grower by the Washington State Department of Game. However, the maximum payment to any individual grower is $1,000 after the cause of the damage has been properly identified (Oldenberg, pers. comm. 1983). At the present time, deer management and control of damaging individuals is overseen by the Washington State Dept. of Game, which employs several wildlife control officers. Their duties also include predator control, and under contract with the federal Dept. of Fisheries and Wildlife, they provide technical information on rodent control on agricultural lands.

Control measures that have been used to protect crops from damage by deer include: chemical or sonic repellents, attractants, physical barriers, habitat management, and population control (Strickland 1976). Frightening devices such as exploder guns are generally ineffective, giving only temporary control due to habituation (Strickland 1976, DeCalesta 1982). If deer are not extremely persistent, repellents on the base of the plant or on leaves may provide enough protection (DeCalesta 1982). Cougar urine has been used successfully as a repellent in orchards where cotton balls soaked with this substance and placed in tin cans were atached to every fifth tree. This selection of repellent is not often made because of the obvious difficulty in obtaining useful amounts (Strickland 1976). The most constantly chosen repellent is ZAC (zinc dimethyldithiocarbamate cyclohexyamine complex). ZAC is a topical treatment and when mixed with an adhesive compound, which is usually done, the resulting combination is called "ZIP". It has been used effectively in soybeans, orchards, alfalfa, flowers, nursery stock, and truck gardens in Colorado as well as on various crops in New York, South Carolina, South Dakota, and several southern states, which indicates its effectiveness over a wide area (Strickland 1976).

Fencing is recommended by DeCalesta (1982) for vineyards over 10 acres when damage can be expected for several years. It is only cost effective where damage is persistent because of the high cost of approximately $6,000/mile or $1.13/ft. (DeCalesta 1982). As a fence is expected to give 100% control for 15 years or more, the cost is spread over a long period. Interestingly, as vineyard size increases, the cost/acre of the fence decreases. For example, the cost/acre to fence square vineyards of 1, 10, 50, and 100 acres at $1.13/ft. is 943, 330, 141, and 118 dollars respectively. If this cost is spread over a 15 year period, the annual cost/acre for 1, 10, 50, and 100 acre vineyards is 62, 22, 9.5, and 7.8 dollars respectively. It becomes obvious that in larger vineyards with persistent deer problems, fencing may be a sensible answer. Strickland (1976) reports that when fencing large areas, a round fence works better than a square one, because deer are more likely to continue walking around it.

Shooting deer out of season requires a permit from the Washington Dept. of Fish and Wildlife, and is difficult since the damage is usually done at night. This approach does not usually solve the problem because in most cases the damage has occurred before the permit to shoot is obtained (DeCalesta 1982).

Habitat management has been used with varying results in forestry situations as an attempt to reduce damage to young trees. This usually takes the form of planting desirable forage species that will attract deer and minimize their effect on young trees. Attractants such as this are not so useful in agricultural areas. Damage to orchards has been greater in those with a cowpea cover crop compared to orchards with korean lespedeza or browntop millet covers. Presumably the cowpea cover crop attracted deer, which resulted in more damage to trees (Strickland 1976). As alfalfa is a preferred forage, damage may be higher in vineyards that are adjacent to this crop. Other likely areas where damage in vineyards may be significant is in those vineyards that are located near natural deer habitat (Oldenberg pers. comm. 1983).

Of the growers reporting deer damage, one is located in the Bingen area which has more suitable cover for deer than does most of the wine grape growing region. The other grower is in the Prosser area, in predominantly agricultural land with little protective cover.

Birds

Of the vertebrate pests which can cause damage to wine grapes, birds were the most often reported by survey respondents. The three species most commonly damaging to grapes are the house finch (Carpodacus mexicanus), starling (Sturnus vulgaris), and the robin (Turdus migratorius) (Boudreau 1972). Since starlings and robins dominate the scene in the Washington grape acreage, I shall concentrate on these two species.

Starlings were introduced into North America from Europe in the late 1800s, and in the absence of effective natural controls have become noxious pests in many agricultural situations (Mumby 1978). They were first reported in Washington in the early 1940s, usually seen with native blackbirds. During the 1950s, the number of wintering starlings increased from a few birds to thousands, and by the early 1960s, winter resident populations were estimated by the 100,000s. Some observers have estimated roosting concentrations as high as several million at that time in the Pacific Northwest (Elliott 1964). A pilot program was initiated in Oregon in 1959 designed to develop procedures for effective, safe, and economical starling control. This was in response to damage done by large winter roosting populations to holly orchards in Oregon, and severe losses to cattle feedlot operations where great amounts of feed were being consumed and contaminated by these birds (Elliott 1964). Also threatened at this time was the fruit producing region of eastern Washington, including the Yakima valley. Damage to cherry orchards in the valley led to a year round, large scale live trapping program which started in 1961 and was coordinated between a local cherry cooperative and the federal Department of Fisheries and Wildlife. By the end of 1961, 86 traps were in operation throughout the valley and 15,000 starlings had been trapped. During 1963, there were over 100 traps in service, and damage to the 90,000-ton cherry crop had almost been eliminated. The total starling catch at this time was 110,000 birds (Elliott 1964).

Much was learned of the local starling population during the early 1960s in the Yakima valley and the Northwest as a whole. The damaging stage is the fledgling or young bird; these tend to flock and can be caught easily if the traps are properly located. Best catches were in those traps positioned along well-used flyways and in pasture lands adjacent to nesting sites (Elliott 1964). Banding studies showed that wintering populations in Washington, Oregon, and Idaho tend to migrate north to British Columbia, Alberta, and Saskatchewan for the nesting season. More recent tagging studies in Washington have revealed that nesting birds in the Yakima area, which cause damage to the local fruit crop, overwinter in the milder climate of western Washington, and also as far south as California. In addition, there is a resident population which varies in size from year to year depending on weather conditions (Oldenberg, pers. comm. 1983). Although it is known that these various populations coexist and overlap geographically at certain times of the year, little is known of the percentage of the total which each sub-group represents.

Although the concern in the 1960s was the cherry crop, the threat of this pest to grapes was realized in the late 1960s. With the recent increase in wine grape acreage in the area, and the damage potential that has been seen in other wine regions, notably California, now is a good time to examine past practices and evaluate different control tactics for the Yakima valley, where there is at present no organized trapping program in place.

Starlings are well known for their roosting behaviour both in the summer and winter. Roosting sites are often shared with grackles, cowbirds, robins, red-winged blackbirds, and Brewer's blackbirds. Starlings leave roosts in a concentric pattern and normally feed within 50 miles of this site (Mumby 1978, Flaherty et al. 1982). They are communal feeders and most active in the early morning and again in the late afternoon, consuming from 1/3 to 1/2 their body weight in food each day. They are considered opportunistic feeders, and hence exhibit great adaptability in the type of food consumed. Insects and fruit make up most of their diet in the summer, fruit in the fall, and whatever is available in the winter (Mumby 1978, Elliott 1964). Feedlots, poultry barns, and dairies are common feeding sites in the winter, particularly in semi-arid regions where grain is in open troughs and readily available (Oldenberg, pers. comm. 1983, Besser, Royall, and DeGrazio 1967). During the winter, starlings can be under extreme physiological stress, and their maintenance requirements increase due to cold temperatures (Mumby 1978). Roosting sites are often close to food sources during the winter.

In the Pacific Northwest, preferred nesting sites are in box elder, cottonwood, willow, maple, lombardy poplar, and apple trees in descending order of preference. Two broods are raised annually, each averaging five young. Protein requirements are high for the young, so that insects are the major source of food in the spring. The first brood leaves the nest in early May, and the second brood leaves in mid-June (Bogatich 1967). These fledglings group together and the degree of damage caused is largely governed by the density of the breeding population (Elliott 1964). In the Yakima valley, small flocks will develop in widely scattered areas, usually in irrigated pasture land. These young birds are easily caught by setting up traps in these communal areas or along well-used local flyways (Bogatich 1967). As the grapes mature to about 12% sugar, feeding by starlings will begin. Brown (1974) has speculated that fruit may be an important food source in the fall, due to its high carbohydrate content, allowing birds to build up a fat reserve for migration. The concentrated sugar solution found in fruit is easily converted to usable fat. Fruit may also be attractive to birds because it is a source of water. Feeding behavior is complex and not well understood in many bird species (Brown 1974). Through studies of robins in the Niagara Peninsula area, Brown (1974) concludes that robins begin to feed on fruit due to a positive preference, not through lack of availability of other food sources.

Damage to grapes from birds is in several forms. Starlings and robins usually pluck the grape, consuming it whole, whereas the house finch pecks at grapes. Pecking can lead to high losses, because the grape is then easily invaded by rot organisms. It is important to realize that the type of damage provides clues which help to identify the species responsible (Boudreau 1972). Other damage is due to shattering or knocking grapes to the ground, and the attraction of damaged grapes for wasps which are annoying to pickers.

Losses due to birds have been reported as high as 82% (Dehaven 1973, Vaudry 1975) and as low as 0% by the same authors. Dehaven (1973) surveyed 47,000 acres of wine grapes in central California, which made up 32% of the total bearing acreage in the state at that time, to estimate yield reduction resulting from bird depredation. The losses ranged from $.44/acre to $438/acre. Damage to early and late maturing varieties was not significantly different. He found that damage to dark colored varieties was significantly greater than to light varieties, and that the level of damage experienced by a vineyard was largely related to proximity of roosting, loafing, and perching cover. Normal damage from birds has been reported in Ontario (less than 10% of crop), California (less than 1% of crop), and in the Okanagan and Similkameen valleys of British Columbia (2% to 17% of the crop) (Mumby 1978).

Vaudry (1975) sent a questionnaire to grape growers in British Columbia, sampling 54% of the total acreage. Starlings were reported as the major pest bird species by 38% of the respondents, followed by robins (32%), cedar waxwing, blackbird and crow. Most of the growers, 77%, reported losses of less than 10%, and half of these experienced losses of less than 2%. Only 5% of the respondents reported crop losses of 80 to 100%, which supports the contention that there are usually a few growers who experience the bulk of the losses. The British Columbia industry is based largely on hybrid varieties, which are virtually non-existent in Washington. The method of control most often used by growers was to shoot to kill. This method is considered to be the least effective because of the amount of time and effort required as well as the consistently poor results (DeCalesta 1982, Vaudry 1979, Flaherty _et al._ 1982, Mumby 1978).

There are four general approaches to controlling pest birds. These are: repellents, direct population reduction, habitat management, and the use of reproduction inhibitors.

Repellents include a variety of noisemakers, chemicals, and visual stimuli. Exploders are generally more effective against starlings than against robins. Brown (1974) found the Av-Alarm to be the only scaring device that was effective against robins, and considered it economically feasible for large scale growers. He also points out that the scaring device needs to be reinforced with kills to remain effective, for birds can become habituated to these artificial sounds within two days of initial exposure (Boudreau 1972).

Bio-sonics, sounds that have some biological meaning for the pest species, such as distress calls, have proven effective for starling control, but overuse of these can also lead to habituation. Large flocks respond better to this tactic than small ones, and adults are more responsive than juveniles. Migrant populations usually respond better to bio-sonics than residents whose behavior patterns are likely to be ingrained (Mumby 1978). Bio-sonics, if used properly, will give longer term control than artificial sounds (Boudreau 1972). Boudreau, who is the director of wildlife management for Almaden Vineyards, uses natural alarm sounds for starlings and finches, reinforced with gunfire. In the Okanagan valley, where most of the damaging birds are migrants, sonic devices can give effective temporary control (Mumby 1978). Shotguns are probably the most often used firearm to scare pest birds. Use of a cracker shell in a shotgun allows the operator to project the explosive to an area in the vineyard where the birds are concentrated. The .22 calibre rifle is reported to be more effective than the shotgun because the range is greater, and the whistling sound produced as the bullet moves through the air gets a better response (Vaudry 1979). Even music projected over the vineyard has kept birds from entering the crop (Vaudry 1979).

There are numerous visual repellents including scarecrows, metal foil pie plates, raptor balloons, predator models, and streamers of flagging tape. These and more can be effective deterrents if they are highly visible and moved about to reduce habituation (Vaudry 1979). Predator models suspended from balloons have given good results, but they are expensive, easily damaged by high winds, and must be moved at least 75 ft. each day to remain effective (DeCalesta 1982). Suspending dead birds of the same species as the pest adds effectiveness to a program (Vaudry 1979).

The chemical repellent Mesurol, which was available in Washington under a temporary special use permit for the 1983 season, is probably the best method for reducing crop losses to both starlings and robins (DeCalesta 1982). It is sprayed on a portion of the acreage, usually on the heavily visited areas, or on the total acreage in early September as a preventative. This initial application can be followed by additional sprays at 1 to 3-week intervals. The need for additional sprays is a function of the grape variety complex in the vineyard as well as past experience and present pressure from birds. The cost can be quite variable depending on the percentage of acreage treated and the number of applications. DeCalesta (1982) estimates a cost of $50 to $100/acre to reduce losses by 60 to 95%. Expected losses of 2% to 5% of the crop would justify its use. This is at present the preferred tactic by Washington producers as indicated by questionnaire response. Mesurol also has insecticidal properties and therefore its use may provide late season insect control.

There are several tactics available within a population reduction strategy. The main choices are shooting birds at the vineyard, poisoning them at or near the vineyard during damage periods, poisoning at other sites such as feedlots during the winter, and trapping. Shooting birds is costly, time consuming, and generally ineffective. Toxicants are not usually used in vineyards because of potential non-target effects and the low acceptability by birds of treated baits in the presence of desirable fruit. However, some toxicants are used in conjunction with trapping to eliminate trapped birds.

Poisoning at feedlots has proved to be an effective population reduction tactic aimed at wintering starling populations. During the winter, large flocks of starlings will descend on feedlots and use them for a primary source of food. The Dept. of Fish and Wildlife in Washington has an ongoing program at feedlots, where grain is treated with DRC 1339 (Starlicide, 95%AI). This toxicant is very selective for starlings, and is slow acting, so that the birds make no association between their feeding behavior and the toxic effect of the treated grain. Kills at individual feedlots can be well over 100,000 birds (Oldenberg, pers. comm. 1983). This toxicant may be used only by Fish and Wildlife personnel. This control program throughout Washington state, although designed to reduce losses at feedlots, probably helps to reduce pressure on any nearby fruit producing area. Studies performed in seven states from 1964 to 1965 with DRC 1339 in feedlots showed an average reduction of 78% of the roosting population (Ford 1967). One part of treated poultry pellets are diluted with 10 parts of untreated cracked corn to minimize non-target poisoning. Starlings prefer poultry pellets and blackbirds in particular prefer the cracked corn (West, Besser, and DeGrazio 1967). Success has also been achieved by baiting pasture areas which are often used as pre-roost sites during the winter. Non-target kills have been limited to red-winged blackbirds; in one case, 10% of the population was killed (West 1968). Besser et al. (1967) have reported good starling control at feedlots using DRC 1339, with no harmful effects on white-crowned sparrows, house sparrows, crows, red-winged and yellow-headed blackbirds, brown-headed cowbirds, and feral pigeons, which were all feeding in the area. At the present time, DRC 1339 meets the requirements of an effective starling toxicant. With high toxicity to starlings, it has low toxicity to mammals. There is little aversion of starlings to the treated baits and a slow, non-violent death results, which poses the minimum hazard to non-target avian and mammalian predators (Ford 1967).

The trapping program that was in effect in the Yakima valley in the early 1960's effectively controlled starling damage to cherries (Elliott 1964, Oldenberg, pers. comm. 1983). The Dept. of Fish and Wildlife presently operates trapping programs using the MACT (Modified Australian Crow Trap) in five counties of eastern Washington. Their strategy is to keep the area populations below economically damaging levels during the growing season. These efforts, supported by farmer cooperatives, are directed toward controlling damage to apples and cherries. The field staff of four men spend about 80% of their time maintaining these traps. Trapping in and near orchards is carried out from May to October. For about $5,000, the Yakima valley could implement a seasonal trapping program managed by the Dept. of Fish and Wildlife to reduce fruit crop losses. From 30 to 50 traps, properly located throughout the valley and regularly serviced by one worker from May to October would be needed in a trapping program. A program such as this could be provided by the Dept. of Fish and Wildlife or a private consultant (Oldenberg, pers comm. 1983). Brown (1974) considers the large-scale trapping of starlings to be technically and economically feasible and the best strategy. For trapping to be effective, it is important to maintain the traps well by supplying clean water regularly and live decoys to help attract other starlings. Knowledgeable placement of the traps is critical in order to be successful. Vaudry (1979) recommended a trapping program in British Columbia which is overseen by local growers who hire a manager to maintain traps. McCracken (1972) estimates that with proper placement of a trap, starlings can be pulled in from a 5-mile radius. He has had good results in Sonoma county, California, controlling starlings in vineyards. Clark (1967) also reported that trapping was the most successful strategy for starling control in Tulare county, where a trapping program was started in the early 1960s. Trapping is most useful in reducing losses from resident birds, but not of much value when large flocks descend on a vineyard (Flaherty *et al.* 1982).

Wetting agents sprayed on large roosts in the winter can result in high mortality if the spray is followed by ideal weather conditions. This technique is not feasible in Washington because most of the roosting sites are too close to water to allow for the safe use of these chemicals (Oldenberg, pers. comm. 1983).

The objective of chemosterilant use is to inhibit reproduction, resulting in a reduced birth rate, and hence fewer juvenile pest birds. There are several types of reproductive inhibitors and among them are gametocides, thyroid inhibitors, hypophyseal inhibitors, pesticides, and hypocholesterolemic agents. To be effective, an intimate knowledge of the movement of breeding birds before and after the breeding season is needed. Due to the lack of such knowledge in most areas, chemosterilant use is quite limited (Mumby 1978). Chemosterilants are further limited because of the mobility of migrating species such as starlings and robins. Positive effects of local sterilization would be erased with the addition of incoming migrants. Mumby (1978) postulates that for chemosterilants to be effective, they would have to be used on a very large scale, demanding cooperation between the U.S. and Canada. This is unlikely to take place. Other options are available, such as Mesurol, and undoubtedly a public outcry would result from large scale use of chemosterilants.

Habitat management for reducing losses can take many forms. The aim is to eliminate factors within a vineyard that may attract pest birds. Boudreau (1972) reduced losses in a 60 acre vineyard from 5 tons per year to 1/4 ton by removing weeds from along one side. Elimination of perching sites around vineyards tends to reduce depredation by robins. In general, heavy grape foliage will deter several pest bird species, since with a heavy canopy, the grapes are not easily noticed by birds. Vaudry (1979) recommends altering grape trellising systems to maximize foliage. Some preferred trellising systems are T-bar, Geneva double curtain, and overhead systems. Insects can also attract birds into a vineyard, and therefore good late season insect control may be an effective way to reduce losses (Boudreau 1972). Eliminating standing pools of water, which birds use for drinking and bathing will reduce attractiveness (Mumby 1978). Mumby (1978) mentions the use of spoil crops planted near vineyards to draw starlings away from the crop to be protected. But Brown (1974) is not optimistic about the use of spoil crops for two reasons: firstly, one would have to plant an uneconomically large amount of such crops to reduce damage in a vineyard, and secondly, the presence of wild fruits does not necessarily protect cultivated ones. In addition, bird control measures in the Northwest may be necessary over a 30 to 60 day period depending on the complex of varieties and differences in ripening dates. If a spoil crop provided relief, it would be only temporary. Any actions which support local raptor populations will be beneficial to grape producers.

The choice of pest bird controls depends on the physical parameters of the problem area, the behavior pattern which is to be eliminated, the problem species, and the intrinsic qualities of the control procedure (Mumby 1978). The degree to which the birds are accustomed to the pestiferous behavior and the rate of habituation are important factors governing the rate of success of any control effort.

The Yakima valley is a well defined irrigated agricultural area surrounded on the north and south by desert vegetation which does not support large numbers of resident pest bird species such as robins and starlings. For this reason and with past successes in mind, I think that a live-trapping program, if managed properly, could significantly reduce the impact of local starlings on wine grape vineyards. It is possible that bird depredations in vineyards will increase as the acreage continues to expand and local birds begin to take advantage of the expanded food base, incorporating grapes into their seasonal feeding pattern. Conversation with Oldenberg reveals that grape growers are seeking advice from the Dept. of Fish and Wildlife, and he considers that the grape acreage expansion will intensify the bird problems. Continuation of the feedlot control efforts in Washington and other Northwest states should reduce wintering populations of starlings and fruit damage in Washington as well as British Columbia, where many of these birds nest and cause damage later. Control of starlings at feedlots in Oregon and California as well as western Washington should reduce the numbers of incoming starlings which nest in the Yakima valley and produce pestiferous offspring. In addition to these population control measures, growers must continue to make imaginative use of the variety of repellents that are available and consider any reasonable habitat modifications.

There is need to assess accurately the losses that are actually due to bird depredation on grapes, in order to choose cost-effective controls. Most estimates of bird damage and vertebrate pest damage in general, are based on grower's estimates from surveys, rather than on regular, quantitative inspection in the field. One of the most important considerations in bird control is to have repellent tactics operational before the birds develop feeding patterns (Vaudry 1979). Vaudry (1979) suggests that bird damage should be assessed regularly to determine the need for control measures. The decision to implement controls is then based on the value of fruit lost and the cost and effectiveness of control. Work by Vaudry (1975) and communication with Kluge (1983), suggest that growers in British Columbia need to determine their crop losses accurately in order to define economically sensible controls. At present, in Washington, growers seem satisfied with a preventative Mesurol program ranging in cost from $6/acre to possibly as high as $150/acre depending on the percentage of acreage treated and the number of applications. The high estimate is equivalent to 6% of the value of the average crop yielding 5 tons/acre. Mesurol use in Oregon is estimated to reduce crop loss by 60 to 95%. Monitoring the damage to help time the application of Mesurol may be realistic in vineyards that normally receive little bird pressure, but is of no use in vineyards that can expect heavy visitations from pest birds. In these vineyards, it may be necessary to have a preventative spray on the vines. Growers who consistently experience heavy bird pressure should consider other tactics such as habitat modification or trapping.

Proper identification of the damaging species by direct observation and analysis of the damage is critical if control efforts are expected to succeed and be cost effective. Good records from year-to-year will also help to identify problem vineyards and evaluate the success of various tactics. As long as Mesurol is available in Washington, it will probably continue to be widely used because it reduces damage caused by both robins and starlings, and it is more time efficient than the alternative repellents which must be adjusted regularly to minimize habituation.

Table V lists vertebrate pests as reported by vinifera growers surveyed in Washington.

Table IV Vertebrate pests reported by vinifera growers surveyed in Washington

Common name	Latin names [a]	# Growers reporting as problem
BIRDS		29
Robin	*Turdus migratorius*	27
Starling	*Sturnus vulgaris*	21
Magpie	*Pica pica*	5
Sparrows		2
Pheasant	*Phasianus colchicus*	1
Red-shafted flicker	*Colaptes cafer*	1
House finch	*Carpodacus mexicanus*	1
Blackbirds		1
Woodpeckers		1
MAMMALS		14
Northern pocket gopher	*Thomomys talpoides*	6
Ground squirrels	*Spermophilus townsendi*	4
	S. washingtoni	
	S. columbianus	
	S. beecheyi	
Rabbits and hares	*Sylvilagus nuttallii*	2
	S. idahoensis	
	S. floridanus	
	Lepus americanus	
	L. townsendii	
	L. californicus	
Deer	*Odocoileus hemionus*	2
	O. virginianus	
Coyote	*Canis latrans*	1

a Where species are not listed, several are possibilities.

IV. Grower Questionnaire

Design

In the spring of 1983, a questionnaire of 34 questions was hand-delivered to 32 wine grape growers in central Washington, and each was completed in the presence of the author. This exercise was designed to identify the present pest species, costs of pest control, and sources of pest control advice used by growers. The attitude of growers toward improved pest management based on monitoring in the field was measured through the growers' response to a proposed pest management service and their estimation of a reasonable fee for the described service.

The questions were designed by the author following discussions with agricultural research and extension personnel associated with W.S.U.. Format of the questionnaire was adjusted following consultation with computer advisors at Simon Fraser University in order to simplify data entry and interpretation. Certain representatives from the wine grape industry in Washington were also helpful in shaping the questionnaire.

The 32 growers surveyed represented farm sizes ranging from 4 acres to 2800 acres (see appendix B). Although only about 30% of the total number of wine grape growers in Washington participated, this apparently small sample represents 65% of the total acreage planted at the time (7906), and 82% of the bearing acreage at the time (3404). Bearing acreage included vines planted in 1979 or earlier. Since the survey has been completed, an additional 1500 acres which was planted in 1980 has come into production. At the time of the survey, there were approximately 7900 acres of wine grape vines planted in Washington (Folwell et al. 1983).

Because information on farm size distribution was not available, the sample population may not be a statistically valid representation of the entire industry based on this criterion alone. However, the full spectrum of farm sizes was surveyed, and no particular size class was avoided or not represented.

Individual growers were chosen largely for their willingness to participate, rather than on the vital statistics of their particular farm. Of the 32 growers surveyed, 19 were at the time receiving free pest management advice from Chateau Ste. Michelle, with whom their grapes were contracted.

Sources of Advice

According to the survey results, farm supply fieldmen provide most of the advice on weed, insect, disease, and vertebrate pest control. Growers were asked to list the three main sources of pest control advice used; 19 growers chose farm supply personnel. Winery fieldmen were chosen by 18 growers, all of whom benefit from services offered through their association with Chateau Ste. Michelle, which at that time was the only winery offering pest management advice to its growers. Most growers in Washington do not receive free, high quality advice from wineries with whom they contract. The third most preferred source of advice, chosen by 11 growers, was the Cooperative Extension Service. Information is transferred primarily through the Spray Guide for Grapes, which is updated annually and available to growers at low cost. This publication serves as a production guide, to be used as a quick and easy reference for timing pesticide applications and choosing chemicals as well as calibrating sprayers and other information. Periodic seminars are also available to interested growers as well as a news letter, which is sent to members of the Washington State Grape Society to update them on industry trends and remind them of upcoming viticultural operations including pest control. The Spray Guide for Grapes was listed as the main pest control reference by 9 growers.

Ten growers rely heavily on their "own expertise" in making pest control decisions. The degree of expertise is quite varied, however 3 of the 10 are trained in either viticulture, pest management, or biology and each of these has a management level job with some of the largest wine grape producers in Washington. All are aware of the need to improve pest management in this crop, are active in conducting their own field trials, and help to steer local research.

"Other growers" were chosen as a main source of pest control advice by 7 respondents. This is mostly on an informal basis, although some growers charge a fee for this advice. Books were chosen as a main source of advice by 6 growers, followed by trade magazines (4), literature review (3), private consultants (3), California extension (1), California farm supply (1), and winemaker (1).

Present Satisfaction

Growers were asked if they were satisfied with the pest control advice available at the time. A majority of the growers (17) reported that they were satisfied. Of these 17, 14 had contracts with Chateau Ste. Michelle and received the most progressive wine grape pest management service available in Washington, which is coordinated by a pest management specialist. Of those growers who were not satisfied (15), 10 felt that there was a lack of local expertise available, as well as insufficient depth to, and specifics in, the advice given. The managers of the six largest farms were not content with advice for a variety of reasons, the main one being the lack of local expertise. Two growers were disturbed with what they considered a "conflict of interest" by those who supply them with advice, because the consultants in these cases also benefit by selling pesticide products.

Grower's Attitudes Toward Adoption of a Pest Management Service

A pest management service, which could be developed for wine grapes and would stress field monitoring by a trained pest manager prior to recommendation, was described to all of the survey respondents. Each grower was then asked if they would consider using the service, and all were asked to estimate what they would consider a reasonable fee.

Most of the growers (19) said they would consider using the service described. These 19 growers collectively manage 1723 acres of wine grapes. Of these, 11 manage vineyards that are 50 acres or larger, and the average farm size of these 19 producers is 90 acres. Chateau Ste. Michelle, though they support improved pest management, would not consider using the service described because they have their own trained staff available. Subtracting their 2800 acres from the total surveyed (5062) leaves 2262 acres available. Of this acreage, 19 growers representing 1723 acres support implementation of the described service, and 12 growers representing 539 acres were not interested. Therefore, managers, excluding Chateau Ste. Michelle, who were interested in the described pest management service, though they represent 62% of the people surveyed, manage 75% of the acreage that is available for a service (See Figs. 3-5). Present satisfaction reported by growers could not be related to attitude towards adoption of the described service. For example, 9 of the 19 growers who would consider using the service reported earlier in the survey that they were satisfied with available advice. Of the 15 who reported that they were not content, 10 would consider using the service. Six growers were undecided about adoption of the service, and 7 were not interested.

Fee Estimation

The growers' estimation of a fee for the described service was in response to an open-ended question. Responses ranged from $5/acre/yr. to $50/acre/yr. The simple average of 17 growers who responded to this question was $20. Of these, 13 indicated a fee of at least $15/acre/yr. as reasonable. Of the 19 growers who would consider using the service, 5 did not respond to this question for whatever reasons. Several growers (16) felt that a consultant service was more attractive if services in addition to pest management were offered. Additional services mentioned were fertility recommendations by 9 growers, water management (5), and advice on cultural practices such as pruning (5). These additional services increased the attraction of the service to 11 of the 19 who would consider using the described service alone, and to 5 growers who previously responded negatively to a pest management service. Therefore, the availability of services in addition to pest management offered by the same source, increased the number of growers who would use a pest management service from 19 to 24, an increase of 26%.

Pest Management Service Affiliation

Regardless of the growers' attitudes toward adoption of a pest management consultant service, 23 growers felt that this service should be provided by someone from the private sector who is not employed by a winery or a chemical company. Five growers said that such a consultant should be affiliated with the winery contracting to buy their grapes, and 3 felt that the service should be provided through some form of grower association (See Fig. 6). Of the 19 growers who showed interest in the service, 15 preferred an independent private consultant, 3 preferred a winery representative, and 1 was undecided.

Pesticide Costs

Respondents were asked to provide pesticide costs for the 1982 season. Costs were reported by 27 growers and estimations ranged from $25/acre to $125/acre. Four growers did not know what their pesticide costs were for the period, and one felt that this information was confidential.

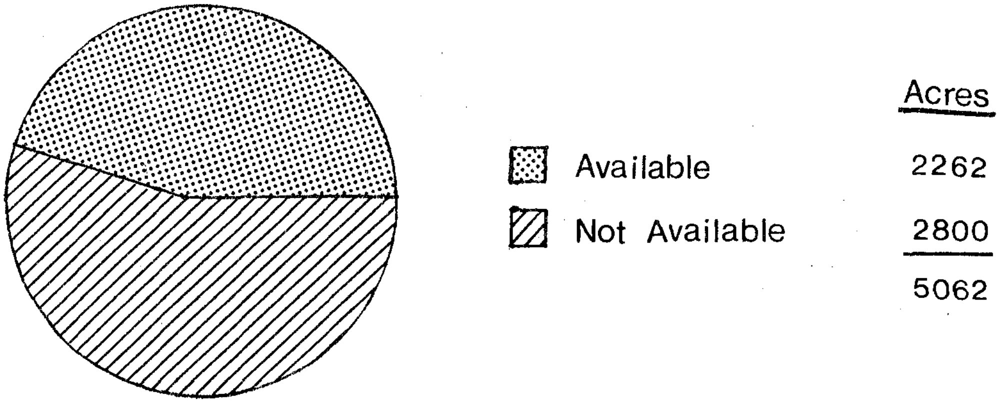

Fig. 3. Breakdown of total acreage surveyed based on availability for the proposed pest management service.

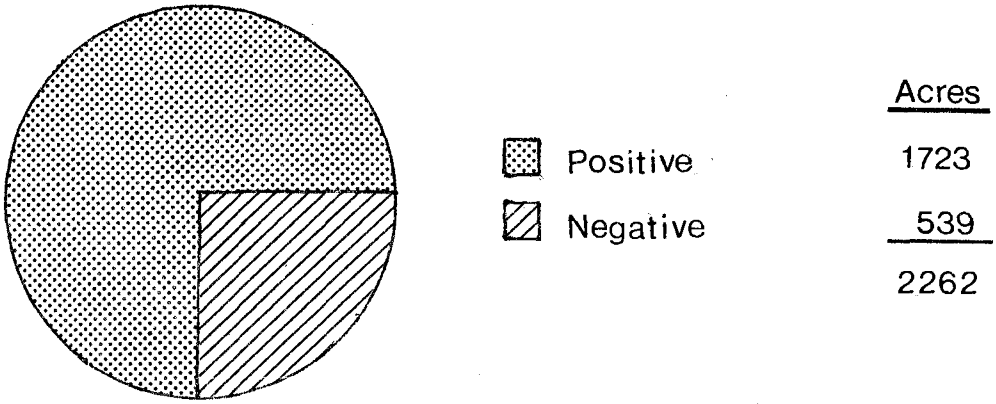

Fig. 4. Breakdown of available acreage based on attitude toward the adoption of the proposed pest management service.

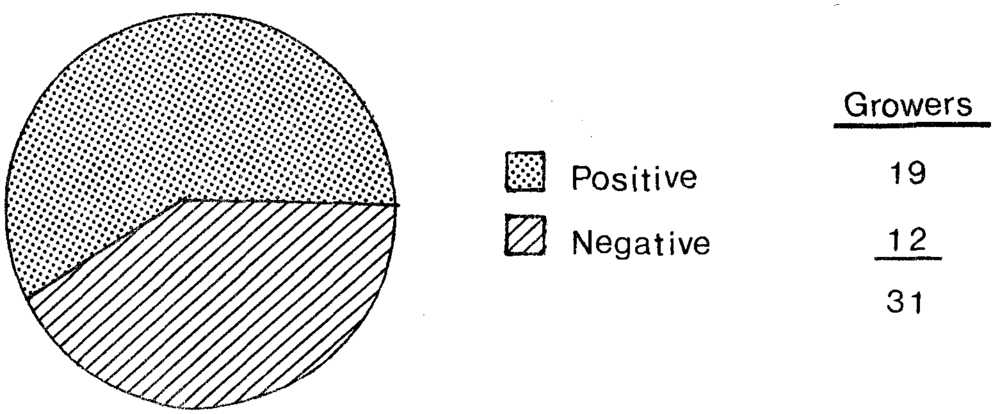

Fig. 5. Breakdown of growers surveyed excluding Chateau Ste. Michelle based on their attitude toward adoption of the proposed pest management service.

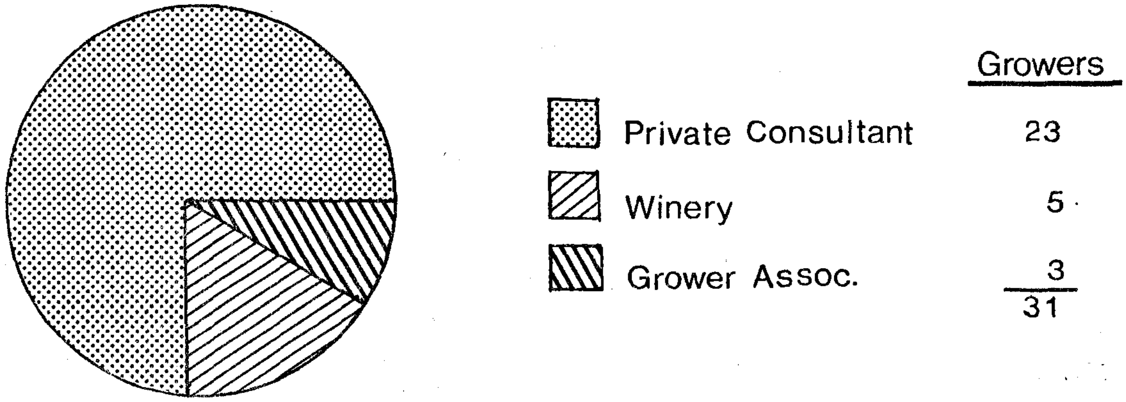

Fig. 6. Preferred affiliation by growers surveyed of the proposed pest management service.

V. Conclusion

In studying the pest management potential in the wine grape industry of central Washington, this paper has considered many factors. Included are: the economic status of the industry, growers attitudes toward pest management, pest control costs as they relate to total production costs, and the biology and control of grape pests presently encountered. Although there has not been enough research conducted in wine grapes in Washington up to this point to allow for the implementation of an integrated pest management (IPM) program, this study represents a preliminary summary with this eventual goal in mind.

It is obvious that the Washington wine grape industry has grown dramatically in terms of acreage in recent years. Between 1980 and 1982, 4502 acres of vines were planted. Given the current international market, which is characterized by an abundance of product, reduced prices, and increased U.S. sales of foreign wines, growth should be at a lower rate in the near future. The effect that this situation has on grape growers is indicated by a recent plan of the California Association of Wine Grape Growers to file an unfair trade complaint against the Italians with the U.S. government. This is because the Italian growers are heavily subsidized by their government, which results in unfair competition between U.S. and Italian produced wines and reduced prices paid to U.S. growers (Mapes 1983). Long term projections for the Washington industry depend largely on wine consumption trends and many other factors beyond the scope of this study. However, although there appear to be economic constraints at the present, potential growth is not limited by land suitable for vinifera production. The area is becoming recognized as a quality wine grape growing region; this is supported by the fact that the Yakima Valley recently received "appelation" approval. A major thrust of wineries at present is to increase in-state and national sales through more effective marketing.

Although the number of wineries is increasing, expansion in grape production has been more rapid. This situation increases competition between growers and demands that they optimize production inputs in an effort to maximize their net returns. The high initial investment in vinifera production, as well as the attractive potential returns to the producer, favor the feasibility of services that are related to improving production efficiency. A pest management service which aims to optimize pest control through regular field monitoring is one of these services.

In addition, pest control costs representing about 6% of total production costs and 14% of variable production costs are relatively high. This cost will most probably increase rather than decrease as more vineyards mature. These estimates may also be low because some present pests are not considered and others may rise in importance. At present, based on an economic worksheet designed by Strong to evaluate IPM application to crops, IPM technology once developed will be appropriate. For IPM to be economically feasible according to Strong, pest control costs must be greater than 5% of variable production costs. This situation exists for vinifera in Washington.

Through my discussions with growers as well as their response to the questionnaire, it was evident that most have a positive attitude toward the adoption or improvement of pest management services. Grower acceptance is essential in order to eventually implement IPM. The estimation of a fee for a pest management service averaged $20/acre. This is encouraging, because this is approximately what orchard pest management consultants are charging in the area. Another attractive feature to the private consultant is that most of the grape acreage is accessible and within a fairly small region, minimizing travelling costs. Also encouraging was that of 32 growers surveyed, 23 preferred a pest management service provided by an independent consultant not affiliated with pesticide suppliers. This approach coincides with desired IPM development and implementation strategy, whereby pest management tools are developed through government directed research and then transferred to the private sector. This not only reduces the burden of pest management on extension services, but also provides meaningful jobs for the private sector.

From a biological perspective, perennial crops like grapes are well suited to integrated management because disruptions can be kept to a minimum, allowing for a more diverse insect fauna and a higher potential for biological control by natural or introduced pest enemies. A good example of this is the control of the grape leafhopper in some areas of California through habitat alteration which favors the naturally occurring parasite, A. epos and in some cases eliminates the need for pesticide application to control this pest. Much work needs to be done to fine-tune pest control decision making on wine grapes in Washington. At present, locally determined action thresholds are available for few pests. However, application of thresholds used in California adjusted to local conditions through experience is practiced by some managers and can be an improvement.

I have compiled a list of major pest categories and the components within each based largely on grower response to selected questions from the questionnaire (see Table VI). Decision making tools are most developed for the insect pests; leafhoppers and cutworms. Monitoring leafhopper nymphs and measuring bud damage from cutworms can lead to sensible recommendations, and are services that could be offered by a pest manager. Disease control at present is based on protectant programs which are designed to eliminate initial infection, primarily of powdery mildew and botrytis. However, monitoring disease incidence and spread in the vineyard and damage assessment are worthwhile services that a consultant could provide. With the increasing use of systemic fungicides for powdery mildew control, timing of application can be optimized through effective monitoring in the field. Bird damage to grapes can either be slow and steady or rapid and catastrophic. Therefore the nature of the service provided depends on the history of bird problems in specific sites. If a site is usually heavily damaged or visited by birds, it is probably best to protect against damage by using a repellent spray and to periodically measure damage to assess cost effectiveness of the treatment. In lightly visited sites, a consultant could best serve the grower by regularly measuring damage to determine when controls are justified economically, thus possibly eliminating the need to treat. To reduce overall damage from starlings, a consultant service could either provide or promote a live trapping program throughout the major production area.

In terms of vegetation management, the consultant is in a good position through exposure to several different vineyards, to keep a record of cover cropping systems and their relationship to insect pest intensity. Identification of problem weeds and herbicide recommendations could be provided also. The consultant is also in a good position to make the grower aware of any possible associations between weeds and other pests.

Research on nematodes is in its infancy at the present. The most important effort now is to sample vineyard acreage in order to establish relative population sizes and identify species. This service could be provided by a consultant in coordination with extension personnel and though it may not lead to precise control recommendations due in part to the present lack of economic threshold values, will aid in determining the need for control in the future. Pre-plant sampling for nematodes is a service that should be in demand since controls are only available in pre-plant situations and knowledge of the presence of this potential pest may influence the decision to develop a site for viticultural use.

Vertebrate pest management advice would in most situations be a supplementary part of a service as few growers experience heavy losses at the present time.

Table VI Major Pests of Vinifera in Washington Based on Grower Response to Selected Questions and the Cost of Control as Estimated by Kirpes and Folwell(1983)

Pest	# Growers Reporting Regular Control Action	# Growers Reporting as 1 of 3 Most Persistent Pests	% of Total Pest Control Cost
Insects	19	16	15
Leafhoppers	13	11	
Cutworms	16	8	
Disease	31	25	53
Powdery Mildew	31	23	
Botrytis	12	9	
Weeds	29	13	28
Birds	29	17	4
Robin	27	17	
Starling	21	17	

IPM Potential

Before an IPM program can be set up, certain criteria must be met. These are well defined and elaborated on by Flint and van den Bosch in Introduction to Integrated Pest Management (1981). There are few agricultural ecosystems for which all of these criteria have been met, but increasing our knowledge in each component that they refer to will lead to more sensible pest management. At the present time there is a good understanding of the biology of vinifera, and the key pests of this crop in Washington have been identified. These are two criteria of several that should be met before constructing an IPM program. IPM programs are built around the key pests, and control action thresholds based on locally determined economic injury levels (EIL) must be developed for these pests. The process for arriving at EILs involves experience in the field and adjustments based on observations from season to season. EILs usually begin at low values and can be adjusted upward with more experience. A major ingredient for sophisticated pest management which is presently missing in wine grapes in Washington is a thorough knowledge of the key environmental factors that impinge on pest and potential pest species of this crop. Basic ecological studies need to be completed for major pests in Washington. Once this information is available, we can more accurately consider concepts, methods, and materials that will help to suppress pest species. For example, we need a better understanding of the relationship between A. epos and leafhoppers to determine the potential of this parasite to suppress leafhoppers and methods by which its effectiveness can be enhanced. Similarily, cutworm populations may be reduced below economic levels by selective weed control in the spring and fall, as has been seen in asparagus.

IPM demands that controls which by their nature have a broad impact on the crop ecosystem be avoided. Rather, controls should be directed at weak links in the pest's life cycle, or chosen based on particular habits of the pest. It is known that leafhopper nymphs are more susceptible to insecticides than the adult stage, and therefore sprays should be timed when most of the population is in this stage. Target pest selectivity can be realized through proper pesticide choice as well as timing. The present recommendation of parathion to control leafhoppers seems amiss when there are other chemicals available which are better suited to the insect's feeding habit and of minimal impact to the ecosystem. Heavy insecticide use could cause an increase in the pest status of mites, requiring even more pesticide applications as has happened in California in the past. By live trapping fledgling starlings in fields adjacent to nesting sites, the weak link in this pest's life cycle has been targeted. Where botrytis rot is a major problem, the cultural practice of removing mummified fruit will reduce the inoculum for the following year.

Where feasible, attempts to diversify the ecosystem may improve stability and suppress potential pests. Habitat alteration similar to the addition of blackberry plants in California vineyards to enhance parasite effectiveness may have potential in Washington. Permanent cover crops between vine rows are associated with a more diverse fauna and improved mite predation in California vineyards. Flowers have also been used in orchards to improve reproductive capabilities of certain parasites and may eventually be feasible in vineyards.

Finally, effective monitoring which leads to sound recommendations is a most important aspect of IPM. This requires the guidance of a well-trained, unbiased professional pest manager. Monitoring systems are available for the key wine grape pests in Washington, and through more field experience and research efforts, action thresholds will become more accurate.

Meeting all of the criteria for an IPM program as defined by Flint and van den Bosch results from years of research and experience with a crop in a particular area. Vines were first planted in California around 1700, and it was not until 1981 that a grape IPM handbook was available for use. Due to the dynamic nature of pest problems and management, improvements will continue to be made and recommendations will vary depending on local conditions. It is important to realize that even though there is much to learn of the pest complex in vinifera in Washington, improvements can be made now with our current level of awareness, which will lead to more effective and safe pest management.

APPENDIX A - QUESTIONNAIRE

1. How many acres of vines do you have in each of the following age classes?

   less than 3 yrs. ________
   3 yrs. plus ________

2. Are you a member of the Washington State Grape Society?

   Yes ____
   No ____

3. Do you plan to join the wine growers association that is being formed?

   Yes ____
   No ____
   Undecided ____

4. Below is a list of possible available sources of advice on grape production . Please rank each of these in order of preference. If you don't refer to a particular source, please rank "0".

Coop. Ext. Service	____	Other growers	____
Farm Supply comp.	____	Winery fieldmen	____
Private consultant	____	County extension	____
Books	____	Magazines	____
Own expertise	____	Other	____

5. Where do you usually get advice on controlling weed, insect, disease, or vertebrate pests? List the top three in order of preference.

   1.____________________________
   2.____________________________
   3.____________________________

6. Do you use the <u>Cooperative Extension Spray Guide for Grapes</u> as your main source of reference for pest control?

   Yes_____
   No _____

7. Are you satisfied with the pest control advice available at present?

Yes ____

No ____

If your answer is no, please explain:

8. Do any of these insects require control measures in your vineyard? If so, please list the chemical used, method of application, and usual number of applications made. If they pose no problem, place a "0" in the last column.

INSECT	CHEMICAL	METHOD OF APPLICATION	NO. OF APPLIC.
Cutworms			
Leafhoppers			
Black Vine Weevil			
Thrips			
Mites			
Grape Twig Borer			
Phylloxera			
Other			

9. How do you decide when to apply an insecticide?

10. Which insects if any, do you check or monitor regularly?

11. Do any of these diseases require control measures in your vineyard? If so, please list the chemical used, method of application, and number of applications usually made. Again, if they pose no problem, place a "0" in the last column.

DISEASE	CHEMICAL	METHOD OF APPLICATION	NO. OF APPLIC.
Crown gall			
Verticillium wilt			
Powdery mildew			
Botrytis bunch rot			
Eutypa dieback			
Other			

12. How do you decide when to apply a fungicide?

13. What diseases, if any, do you check or monitor regularly?

14. How many acres of vines do you have under each of these irrigation systems? What type of vegetation management do you use with each?

	FURROW	OVERHEAD	DRIP	CENTER PIVOT
Acres				
Vegetation Management				

A) Permanent cover crop between rows, residual herbicide under vines.
B) Annual cover crop between rows, residual herbicide under vines.
C) Clean culture between rows, residual herbicide under vines.
D) Natural vegetation covers vineyard floor.
E) Other, please specify:

15. What weeds, if any, are most troublesome in your vineyard. How do you attempt to control these?

<u>WEEDS</u>	<u>CONTROL</u>

16. Do you use herbicides regularly?

Yes ____

No ____

If you answered yes, please explain your normal herbicide program.

17. Do you have difficulty in deciding which herbicides to use?

Yes ____

No ____

Don't use ____

18. Excluding birds, do you have problems with any vertebrate pests in your vineyard?

Yes ____

No ____

If so, what are the problem species, and what measures have you taken to prevent damage?

19. Are birds a problem at any of your vineyard sites?

Yes ____

No ____

If you answered yes, which species are present, and which do you think are causing crop loss?

20. Which of the following control measures have you tried?

electr. noisemakers	____	repellants	____
propane exploders	____	trapping	____
plastic flagging	____	shooting	____
distress calls	____	scarecrows	____
netting	____	other	____

Of the above methods, which do you think are most effective? Please rank the top three.

1. ____________________
2. ____________________
3. ____________________

21. Please estimate in percentage of your crop lost, the damage caused by birds in 1982, 1981, and the average over the last five years.

Percentage crop loss	1982	1981	1978-1982
0-5			
5-10			
10-20			
20-40			
40 plus			

22. Has your vineyard soil ever been sampled to estimate the nematode population?

Yes ____
No ____

23. Are you aware that nematodes sometimes cause substantial yield reduction and may transmit virus?

Yes ____
No ____

24. How much money did you spend on pesticides last year?

Total __________
Don't know _____
Confidential ___

25. What is the percentage of total control cost for each pest category listed below?

PEST	0%	20%	40%	60%	80%	100%
Insects						
Disease						
Weeds						
Birds						
Other						

26. What levels of control do you feel you are getting? Rate as excellent, good, fair or poor.

Insects __________ Weeds __________
Disease __________ Birds __________

27. Which pests do you have difficulty in controlling, if any?

28. Could you use help with:

	Yes	No
Identification of pests		
Timing of pesticide applications		
Choice of chemicals		
Methods of application		

29. What are your three most persistent pest problems?

1. __________
2. __________
3. __________

30. Are these pests generally associated with a particular variety or age class of vines?

Yes ____
No ____

If yes, please explain:

31. A pest management service could be developed which would specialize in wine grape production problems. It might offer the following services:

1. Weekly visit to vineyard during the growing season.
2. Identification and monitoring of major insect and disease pests.
3. Advice as to the need for pesticide application and timing.
4. Advice as to the choice of pesticide and method of application.
5. Advice as to nematode sampling and control recommendations for setting up new vineyards.
6. Advice on control of other pests such as birds, deer, and weeds.

If this range of services were available from a single source, would you consider using it?

Yes ____
No ____
Undecided ____

32. Would a consultant service be more attractive to you if it offered services beyond just pest control?

Yes ____
No ____
Undecided ____

If you answered "yes", what other services should be provided?

33. What do you think would be a reasonable charge per acre for the service described in question 31?

______________.

34. If such a service were available, how should it be controlled?

Growers Association ______
Private business ______
Winery ______

WINERY SUPPLEMENT

35. Do you crush grapes that are purchased from other growers?

Yes ____
No ____

36. Do you supply these growers with pest management advice?

Yes ____
No ____

37. If the answer to question 36 is "yes", could you describe the nature of this relationship?

38. Do you think that there is any particular area or segment of the grower population in which pest management needs improvement?

Yes ____
No ____
Don't know ____

39. If you answered "yes", do you think this segment would use a service such as I have described?

Yes ____
No ____
Maybe ____

40. If a grower contracting with your winery were to use services provided by a pest management specialist, do you foresee any strain that this might place on your relationship with that grower?

APPENDIX B

Sizes of Vinifera Plantings of Growers Surveyed[a]

Grower no.	Non-Bearing Acreage	Bearing Acreage	Total Acreage
1	1500	1300	2800
2	45	450	500
3	218	-	218
4	-	179	179
5	75	85	160
6	-	113	113
7	30	80	110
8	10	100	110
9	35	65	100
10	50	41	91
11	10	70	80
12	58	8	66
13	23	35	58
14	50	7	57
15	13	44	57
16	-	50	50
17	38	-	38
18	25	8	33
19	12	20	32
20	16	16	32
21	2	22	24
22	16	7	23
23	11	10	21

Grower No.	Non-Bearing Acreage	Bearing Acreage	Total Acreage
24	18	2	20
25	-	20	20
26	-	17	17
27	11	5	16
28	7	6	13
29	-	12	12
30	-	8	8
31	-	5	5
32	-	4	4
Total:	2273	2789	5062

a Based on grower response to question no. 1 of questionnaire, (March, 1983).

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