Agroforestry Systems **56:** 185–191, 2002.

The simplification of traditional vineyard based agroforests in northwestern Portugal: some ecological implications

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Received 22 January 2001; accepted in revised form 13 February 2002

Key words: Diseases, Insect pests, Traditional agriculture, Vineyard

Abstract

In northwestern Portugal, peasants have developed complex vineyard (*Vitis vinifera*) systems comprising agroforests composed of host trees, vines, annual crops and in some cases animals. Until recently these vineyards suffered very few pest problems and received relatively low pesticide loads. In the last few years, new policy and market forces have prompted the conversion of many of these systems to monoculture thereby decreasing the biodiversity inherent to traditional vineyards. Many scientists are concerned that with accelerating rates of vineyard simplification insect pest and disease problems may increase due to lack of habitat and resources for natural enemies or to a concentration of preferred host plants for specific pathogens and herbivores. During the growing seasons of 1997 and 1999 we conducted several farm surveys of traditional agroforestry and modernized, monoculture farms. We conducted field measurements to elucidate trends in insect pest and disease incidence in both types of vineyards. Our surveys revealed that monoculture vineyards exhibited lower number of species of predators and parasites and correspondingly higher densities of two grape herbivores (*Lobesia botrana* and *Empoasca vitis*) than diverse vineyard agroforests. *Botrytis* bunch rot seemed more prevalent in the monoculture systems, which also received increased fungicide applications when compared to the traditional vineyards. Although preliminary, our studies suggest that new vineyard designs may be more productive, but such gains occur at the expense of biodiversity and agricultural sustainability, reflected on higher pest vulnerability. Further agroecological studies are needed to account for the full ecological costs of the modernization of traditional vineyard agroforests.

Introduction

Portugal is a country still rich in traditional agriculture. The peasant population is still numerous (traditional and small farms amount for 98% of all producers in the Northwest) and economically significant, playing an important role in the country's economy and food self-sufficiency. The agricultural landscape of Northwestern Portugal is characterized by a pattern of small, fragmented farms that produce mainly for family consumption, interspersed with somewhat larger and more mechanized farms that specialize in commercial crops.

At least since the ninth century, Portuguese peasants have developed complex farming systems, the sustainability of which has stood the test of time. These traditional agroecosystems, which consist of crop polycultures surrounded by vines (*Vitis vinifera*) upon tree-hosts, reflect the priorities of peasant farmers, meeting the needs of a simple, largely self-sufficient peasant society. These vineyard-based agroforestry systems are found mainly in the designated regions of 'Vinho verde' including Minho and a portion of northern Beira Litoral (Stanislawski 1970).

Since Portugal's incorporation into the European Union, agricultural policies have had a major impact on traditional agriculture. Technological modernization of small farms, through monocultures and agrochemicals is perceived as a critical prerequisite for increasing yields, labor efficiency, and farm incomes.

New varieties are being substituted for old ones, and the area is being planted to grape monoculture, featuring continuous fields of short, vertical trellises that permit easy mechanization (Pearson et al. 1987). The shift away from arbor-style diversified vineyards represents a clear pattern of landscape homogenization and loss of agrobiodiversity. Such simplification may contribute to increased pest and disease levels and losses, by creating more favorable conditions to herbivorous insects and fungi (Jones 1998).

The purpose of this study was to test this assertion and to determine whether the best way to improve the productivity of traditional vineyards is through the use of new varieties, agrochemicals and the latest viticulture techniques. We examined whether yield increases resulting from modernization entailed environmental costs, such as increased pest levels, and thus affected the ecological sustainability of small farms. The main indicators used provided an assessment of changes in vine health and incidence of insect pests or diseases following conversion of agroforestry systems to monoculture.

The biophysical and socioeconomic context

The Minho region where virtually all the Portuguese 'vinho verde' is produced lies between 41 and 42 degrees north latitude, facing west towards the Atlantic Ocean. Rainfall is high (about 1500 mm/year) with irregular distribution, reaching low intensity in July and August. Average daily temperature is about 12 degrees Celsius, varying according to distance from the sea, topography, exposure and altitude. Most soils are alfisoils with sandy loam texture, acidic, and are poor in calcium, phosphorous, and potassium, but fertility levels have been improved in most small farms through copious additions of organic matter over time.

Approximately 26% (74,000 hectares) of the agricultural area in the vinho verde region is devoted to grape production. Farm size averages 2.5 hectares where wine grapes are grown on trellises (ramadas) on the borders of cultivated fields. The actual area devoted to grapes per farm is quite small, about 2,200 square meters. Production per farm averages 1.8–2 tons of grapes, or about 1,400 liters of wine. Around 70% of the vinho verde produced in the region is red, however, due to recent market incentives, many farmers are shifting from red to white grape varieties. Although the majority of the vinho verde is still home-processed, cooperatives have begun to seek a wider share of the domestic market. A small number of private farms produce nationally marketed quality wines from their own grapes or the grapes of other farms (Pearson et al. 1987).

The vineyard-based traditional agroforestry systems

Vinho verde grapes traditionally are grown on trees bordering crop fields. The combination of high vine and maize is characteristic of the area. There are a number of traditional agroforestry patterns, all of which represent an ingenious response to land constraints by allowing vertical agriculture (Stanislawski 1970):

1. Association of vines and trees dispersed within fields. This simple system consists of a tree with 4–8 vines planted around the base. The vines ascend and follow the branches.
2. The 'festoon' system where younger cross-branches of the vines join together every year from the nearest trees planted along field margins.
3. The 'arjoado' system is a form of festoon, but with vertical wires attached to the wire that runs between the trees. In addition to planting vines against the tree trunks, several vines can be planted in the intervening area.
4. In the 'ramada' system, grapes are grown on elevated arbors (about three meters high and four meters wide) supported by stone columns with iron crossbars connected to steel wires.

In systems a–c, preferred host trees are Portuguese Oak (*Quercus lusitanica*), elm (Ulmus sp.), poplar (*Populus* sp.), and wild cherry (*Prunus* sp.). The trees tolerate heavy trimming, have deep roots, grow fast and are long lived. Most yield products such as wood, bark, and fruits. Many trees provide additional benefits such as altering the microclimate (interception of winds and lower evaporation rates) and protecting vines from winter frosts of the valley bottom. Trees can also reduce dispersion of weed seeds, insects, and pathogen inocula by forming a physical barrier.

The centers of the fields are available for grain (mostly maize, *Zea mays*), legumes, and vegetables. Normal crop rotations include oat grain (*Holcus lanatus*), rye grain (*Lolium multiflorum*) and the legumes *Ornithopus sativa* and *Trifolium incarnatum*, all used as fodder. Some fields are left fallow for the growth of volunteer legumes (mostly species of *Ulex* and *Spartium*) used for 'cattle beds' in the stalls. After being mixed with urine and feces of the cattle, the semi-decomposed materials of the beds are worked into the soil of the farms as organic amendment.

According to Raposo and Amaro (1997), in northern Portugal, vineyards are affected by various pathogens, insects, and mites. Among insect pests, the tortricid moth, *Lobesia botrana*, is the most persistent one. Of the three generations of this lepidopteran, the two first generations are of greatest economic significance. Leafhoppers are also present (especially *Empoasca vitis*, cigarrinha verde), puncturing leaves and eventually causing leaves to fade, dry up and fall off the vine. Downy mildew (*Plasmopara viticolor*), powdery mildew (*Uncinula necator*) and bunchrot (*Botrytis cinerea*) are the most prevalent fungal pathogens of grapes in the area. Most of these insects and fungi reach, only sporadically, epidemic proportions in traditional agroforests.

During the past ten years, major economic policy-induced changes have occurred in the vinho verde wine industry. Farmers are encouraged to plant varieties that produce better-quality white wines and move away from agroforestry based vineyards to the 'cordao' monoculture system characterized by short, vertical trellises for easy mechanization. Although the systems reduce labor costs and may enhance profit levels, the cordao involves less-intensive land use. The modern system is totally integrated into the market, and little importance is given to production of crops and wine for home consumption (Avillez et al. 1992). In addition the intensification of grape production changes the diversity and microclimate of the vineyard, creating new environmental conditions that may favor some pests.

Methods

During the summers of 1997 and 1999 we conducted farm surveys and interviews with farmers and technicians throughout the northwest region of the Minho (Braga – Guimaraes – Barcelos – Ponte de Lima). Thirty traditional and 20 'modernized' farmers were interviewed throughout the region to gather descriptive information on farm design, crop patterns, use of local resources, and farmers' practices, as well as to understand why farmers adopt particular cropping systems and production methods. The interviews were also designed to assess factors affecting decision making by farmers with respect to the use of crop technologies, and how they avoid risk and adapt to natural and socioeconomic constraints. Direct interviews and observation provided detailed information about biotic constraints affecting productivity and crop management practices, i.e., land preparation, planting, weeding, pest control, fertilization, harvest, etc., their timing, and the amount of inputs utilized in farm operations (Shaner et al. 1982).

Field surveys included the general description of the landscape, identification of existing vineyard patterns, and the actual interactions between the various biological components in the various agroforestry systems. Field measurements were conducted in a few selected fields to elucidate disease incidence and the population trends of pest insects and associated natural enemies, and the resulting degree of pest damage in two dominant vineyard systems:

1. Vineyards under traditional management relying on family labor and low-input technologies (arjoado system).
2. Vineyards in the process of modernization under monoculture and high input management (cordao system).

The entomofauna was sampled by randomly placing 10 yellow sticky traps (10 × 17 cm, Seabright Laboratories, coated with Tanglefoot^{R}) in the middle of each of 10 vineyards (five arjoado and five cordao) to estimate densities of prevalent herbivores and predators/parasitoids (Pedigo and Bunton 1994). Traps were deployed from June through mid September and replaced weekly during 1997 and 1999. Twenty random grape leaves and 20 inflorescences were visually examined weekly in the center of each vineyard, for presence of *E. vitis* and *L. botrana* adults or inmatures respectively. Egg parasitism was determined examining the same 10 grape leaves under a dissection microscope for the presence of parasitized or healthy *L. botrana* or *E. vitis* eggs.

Insect species diversity was estimated using Simpson's measure of diversity (D) and the Shannon-Weaver index (H′) (Pielou 1969). Species richness (MA) was calculated using the formula (^{v}MA) = S − 1/log 10 N. The evenness (J′) component of species diversity was measured using formulas reported by Magurran (1988).

Although powdery mildew (oidio) is the most serious and widespread disease in the region, *B. cinerea*

Table 1. Species diversity measures for foliage insects associated with vines grown in traditional agroforestry and monoculture patterns in Northwestern Portugal (1999)

Diversity measure[a]	Monoculture (cordao system)	Traditional agroforestry (arjoado system)
Total number of species, S	18	32
# of predator species	3	6
# of parasite species	3	8
# of herbivore species	9	11
Total number of individuals, N	79	196
Shannon-Weaver H^1 ± S.E.	2.03 ± 1.7	2.47 ± 1.8
Simpson, D	0.14 ± 0.08	0.36 ± 0.06
Species richness ^{v}MA	8.96	13.6
Evenness, J^1	0.671	0.810

[a] All values are measures of 8 sampling dates and based on yellow sticky trap samples.

was prevalent in some vineyards, which received untimely or low dosages of fungicide applications. Every 20 days, 100 bunches per vineyard were randomly sampled and assessed for infected berries. The proportion of infected berries and disease progress curves in a pair of modern and traditional vineyards were then determined.

Data on the number of leafhoppers *L. botrana* larvae and bunchrot infestation levels in modern and traditional vineyards were statistically compared each sampling date using a *t*-test.

Results and discussion

Patterns of insect diversity, abundance, and pest incidence

In both years (1997 and 1999), the number of insect species and the total number of individuals collected per plot was greater in the agroforestry systems than in monocultures (Table 1). According to both the Simpson and the Shannon measures (expressed as a mean of the D and H values for each plot obtained from eight sampling dates) the species diversity of insects in the agroforestry systems exceeded that found on monocultures. The number of predator and parasite species was substantially greater in the traditional diversified arjoado systems than in the cordao monocultures. Main predator species included various species of Coccinellidae (*Stethorum punctilum* and others), Syrphidae, *Chrysoperla carnea, Orius* spp. and others. Parasitoids belonged predominantly to the family Ichneumonidae, although we detected parasitism of *L. botrana* eggs by naturally occurring *Trichogramma* spp.

In the arjoado systems higher insect biodiversity is probably the result of increased spatial heterogeneity and complexity of the agroforests. The presence of a diversity of crops and also of some weeds in the 'arjoado' increased the amount of food resources (flowers, extra floral nectarines, and alternate prey), which may explain the greater abundance, and diversity of natural enemies. In contrast, the lack of insect biodiversity in mechanized systems was probably due to the lack of plant diversity, and to the higher load of insecticides (mainly organophosphates and carbamates) that cordao systems receive (Altieri 1994).

Abundance monitoring of herbivores was difficult in the monoculture systems as insecticide applications prevented pest population buildup. However, delayed spraying in one modernized farm in 1999 allowed us to compare densities of *L. botrana* and *E. vitis nymphs* between this vineyard monoculture and a neighboring traditional vineyard. As observed in Figure 1, densities of leafhopper nymphs tended to be substantially lower from early June to mid September on leaves in the agroforestry system than in the cordao monoculture. Similarly, from late June to mid-July, larval densities of *L. botrana* where higher in monocultures than in the traditional system (Figure 2) which corresponded with a higher proportion of vine inflorescences infested by *L. botrana* larvae in monocultures than in the vine agroforest (Table 2).

Disease incidence

From interviews we found that as farmers convert their vineyards from the arjoado to cordao (monoculture) system, the amount of recommended fungicide applications increases. The average number of fungicide sprays per year in cordao is 5.7 treatments for

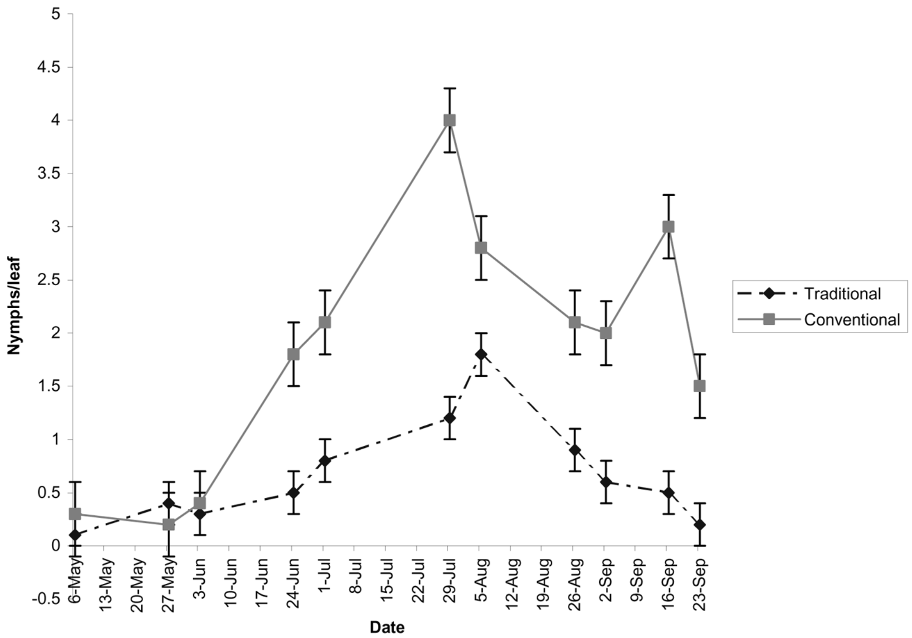

Figure 1. Nymphal densities of *Empoasca vitis* in modern and traditional vineyards in northwestern Portugal (1999).

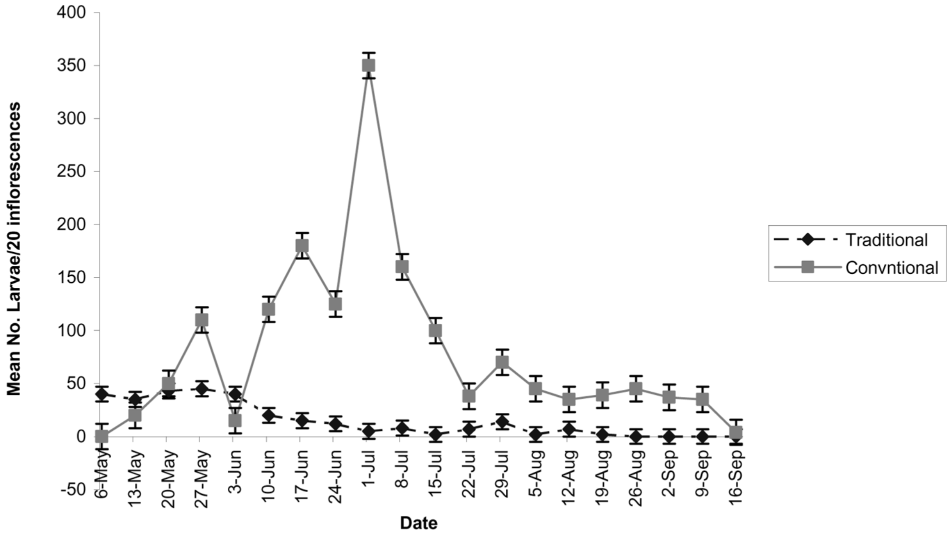

Figure 2. Infestation of grapes by *Lobesia botrana* in traditional and modern vineyards in northwestern Portugal (1999).

downy mildew (mildio), 6.4 for powdery mildew (oidio) and 1.1 for *Botrytis* bunch rot. Copper formulations and several organic contact and systemic products are the main fungicides used against the three main fungal diseases. In traditional systems sulfur and Bordeaux mixtures are the most prevalent treatments (3.5 average sprays/year), although some traditional farmers use fungicides.

Heavy applications of fungicides did not allow us to comparatively monitor disease development in agroforestry and monoculture vineyards. However in 1997 we were able to compare disease severity in two systems (modern and traditional) both of which for various reasons did not receive applications of sulphur or fungicides. Figure 3 shows the disease intensity over time, suggesting a reduction in *Botrytis* incidence in the traditional system. A number of factors may have contributed to such trends such as differences in temperature and humidity between both vineyards, including the fact that excessive use of

Table 2. Proportion of vine inflorescences infested by *Lobesia botrana* in arjoado and cordao vineyard systems in northwestern Portugal (1999)

	Monoculture (cordao system) (% inflorescences with larvae)[1]	Traditional Agroforestry (arjoado system) (% inflorescences with larvae)[2]
Early June	18 a	17 a
Late June	27 b	19 a
Mid July	52 b	37 a

1. The economic injury level for the first generation has been established in Portugal at 30–100% of infested inflorescences, and 5–10% for the second generation (Roehrich and Boller 1991).
2. Means in each horizontal column, followed by a different letter are significantly different ($P < 0.05$, *t*-test).

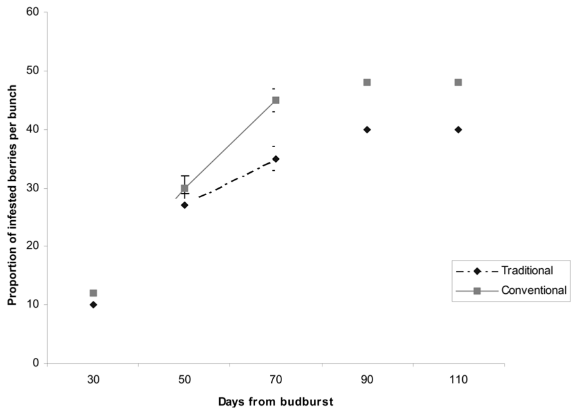

Figure 3. Progress of bunch rot (induced by *Botrytis cinerea*) during the 1997-growing season in a modern and traditional vineyard in northwestern Portugal.

chemical N fertilizer in the modern system may have predisposed grapes to infection by *Botrytis* (Coley-Smith 1980; Jones 1998).

In addition our interviews with farmers, extension agents, and researchers at the Estacao Viti-vinicola Amandio Galhano provided some useful information:

1. Sulfur dust provides adequate control of powdery mildew in traditional systems, but heavy losses can occur if applications are insufficient or untimely;
2. Fungicides used mostly in monoculture against powdery mildew (Mancozeb, Maneb, Zineb, and others) can exert undesirable secondary effects, such as toxicity to the predator *Typhlodromus pyris* and the egg parasitoid *Trichogramma* spp;
3. Vines growing on trees (arjoado system) are less affected by *Botrytis*. Vertical canopy development in such systems increases exposure of the grape clusters to air and light, which creates a microclimate less conducive to development of bunch rot;
4. Arjoado systems with dense top foliage of tree hosts shield lower vine foliage from dew, reducing the attack of downy mildew on the lower leaves; and,
5. Vines on trees are more protected than vines on lower trellises from winter frosts of the valley bottoms.

Conclusions

Peasants in the vinho verde region of northwest Portugal have used traditional grape growing methods for centuries. Vines grown on host trees circumscribe small fields diversified with crops, vegetables, and forage for animals. In these systems, arbor style diversified vines integrated into cropping systems modify the environment of associated understory plants, influencing their growth, pest susceptibility, and yields. The greatest modification for crops apparently results from the interception of wind and some solar radiation, but for vines growing in vertical structures there are clear microclimatic effects. These agroforestry systems are based on family labor and local resources and rely on traditional farming knowledge. Our observations and preliminary field data suggest that agroforestry systems exhibit higher levels of insect biodiversity possibly linked to the higher vegetational complexity of such systems, they are less dependent on external inputs (chemical pesticides), and tend to have fewer insect pest and disease problems than unsprayed modern vineyard monocultures.

Although the shift toward cordao monoculture potentially represents a more labor saving and profitable system, at the same time it can be a risky specialization in production. In the few vineyards where we were able to compare through systematic sampling, our findings suggest that promoted modern technological schemes may be ecologically unsound. Vineyards converted to monocultures exhibited larger numbers of leafhopper and lepidopteran pests, compared to more diversified traditional adjacent systems, featuring the same grape varieties. The fact that these systems, due to recommended practices, require greater application of fungicides is suggestive that these systems may suffer increased incidence of powdery mildew and *Botrytis* bunch rot. The strategy of yield maximization with pest control left primarily to pesticides has increased grape production by 20–35%, but at the expense of higher vulnerability of the vineyards and possible environmental risks.

There is strength in the diversity of traditional vineyards, and it should not be reduced by extensive monoculture, especially when consequences of doing so may result in serious ecological and social problems. Instead, modernization should be guided by agroecological principles, principles whose source are the very traditional systems that modernity is destroying. As rural change occurs in Portugal given EEC driven agricultural modernization trends, knowledge of traditional management practices and the ecological rationale behind them is gradually being lost. For this reason it is crucial to expand studies such as this one in order to gain more insight into the ecological mechanisms that underlie the time-tested performance of these diversified systems. Ecological principles extractable from the study of traditional agroecosystems can be used to design new, improved, sustainable agricultural systems in Portugal, more adaptable to the socio-economic and environmental conditions of the prevalent small farming systems. There is no doubt of the great need to design new systems that are economically competitive, but such systems have to be environmentally sound and socially just as well as culturally compatible. Many traditional vineyard systems provide elements for designing such new systems. However, agroecological research must proceed quickly before all the traditional vineyards in the 'Landscapes of Bacchus' are transformed into large-scale monocultures.

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