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EFFECTS OF CLIMATE AND AGRICULTURE ON EPIPHYTIC LICHEN VEGETATION IN THE MEDITERRANEAN AREA (TUSCANY, CENTRAL ITALY)

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The epiphytic lichen vegetation on *Quercus pubescens* in Tuscany, central Italy, was investigated in agricultural and non-agricultural areas along an altitudinal transect characterized by different climatic conditions. The results show that lichen communities are influenced more by climate than agricultural practices, or at least that climatic parameters can mask any effects of agriculture. The presence and frequency of "nitrophytic" lichen species in agricultural sites was due to the xeric environment exacerbated by ploughing which raises much dust, rather than to nutrient enrichment of the habitat.

Introduction

Several authors (De Bekker 1989; James 1993; Kellner 1993; Benfield 1994) have reported changes in the composition of lichen flora in agricultural areas. A general enrichment of nitrophytic species in lichen communities has been found associated with fertilizer application (Brown 1992). In Switzerland, Ruoss (1993) noted a substantial nitrogen deposition in agricultural areas and a massive presence of nitrophilous lichen species in areas subject to intense agricultural activity.

Some authors (Van Dobben 1993; Van Herk 1993) have suggested that the effect of ammonia on the development of epiphytic lichen species is not due to increased nitrogen availability but rather to alkalinization of tree bark, though it is not known whether the altered pH exercises a direct effect on lichens (Brown et al. 1995). According to Van Dobben & Wamelink (1992), bark pH rises significantly with increasing atmospheric NH^3 concentration, promoting nitrophytic species and inhibiting acidophytic ones, with no effect at all on the total number of species. In the Netherlands, De Bekker (1989) found that in an area subject to intense grazing nitrophytes belonging to the genera *Physcia*, *Xanthoria* and *Candelariella* were the dominant species. Since NO_3 concentrations in the area were very low, the author concluded that ammonia does not cause nitrification but a rise in bark pH. This has a negative effect on growth conditions for acidophytic species and promotes nitrophytic species which need a high substrate pH, rather than high levels of nitrogen.

According to Nimis & Castello (1993), a high frequency of nitrophytic lichen species indicates a primary or secondary eutrophication of tree bark due to agricultural activity. According to Pirintsos et al. (in prep.), grazing in the Mediterranean area induces nitrophytic lichen vegetation because of nutrient enrichment of the habitat and the synergistic effect of dust and light which make the bark drier.

It is worth noting that most studies published so far have been conducted in central-northern Europe and that according to other studies carried out in the Mediterranean area the nitrogen content and pH of tree bark in agricultural areas are no different from those in non-agricultural areas (Loppi & De Dominicis 1996). Even small differences found in the Mediterranean area between agricultural and non-agricultural areas, consisting of a higher frequency of nitrophytic species, are therefore presumably due to other factors. Loppi & De Dominicis (1996) suggested that such differences are determined by the more xeric climatic conditions and by the greater abundance of wind-blown dust in the Mediterranea area.

Climate, mostly in terms of mean annual rainfall, plays a very important role in determining the distribution of epiphytic lichen communities (Loppi et al. 1997; Nimis & De Faveri 1981). Climate is closely related to elevation, which is another important parameter, both as discriminant for the geographical distribution of species and for the spatial heterogeneity of lichen communities (Pirintsos et al. 1993, 1995; Rouss & Vonarburg 1995; Loppi et al. 1997).

Dust can have both a physical and a chemical impact. Lichens may be directly affected by deposited dust, or there may be an indirect effect via changes in bark chemistry (Farmer 1993). Dust can also exacerbate the effects of drought and influence local humidity (Farmer 1993, Recchia & Polidoro 1988). Alkaline dust contamination can cause a rise in bark pH, a secondary effect of which is eutrophication, which leads to the replacement of acidophytic species with nitrophytes of the *Xanthorion* alliance (Gilbert 1976). Loppi (1996) investigated the distribution of epiphytic lichens along a road dust gradient and found that changes in lichen communities due to dust contamination consisted of a shift from acidophytic communities typical of warm-wet habitats *(Parmelietum caperato-perlatae)* in unaffected sites, to neutrophytic communities typical of drier habitats *(Physcietum adscendentis)* close to the source of dust contamination.

The aim of the present study was to investigate whether climate exercises a greater influence than agricultural practices on epiphytic lichen communities in the Mediterranean area. The study was thus designed to answer the following questions: 1) Do substantial differences exist between agricultural areas with different climates? 2) Do substantial differences exist between agricultural and non-agricultural areas with similar climates? To achieve this goal, the epiphytic lichen vegetation was investigated in agricultural and non-agricultural areas along an altitudinal transect characterized by different climatic conditions.

Study Area

The study was performed in central Italy, in the Provinces of Grosseto and Siena (42°30'-43°30' N, 11°00'-11°45' E, Grw). Three areas were selected: Grosseto, Siena and Mt. Amiata, representative of the coastal lowland, hills and mountains respectively. These areas are very well characterized as far as elevation and distance from the sea are concerned, factors which strongly influence the distribution of climatic features such as temperature, rainfall, thermic excursion and relative humidity. The areas belong to three distinct climatic regimes: subarid (Grosseto), subhumid (Siena), perhumid-humid (M.Amiata) according to the classification of Thornthwaite (Barazzuoli et al. 1993). Animal husbandry is not a main activity in central Italy and agriculture consists mainly of crop cultivation. A brief description of the three areas follows.

Grosseto - The area extends inland from the coast including a plain and low hills, with a mean elevation of 10 m. The phytoclimate is typical of Mediterranean evergreen broadleaf vegetation (*Quercus ilex*). Mean annual temperature is 15°C and mean annual rainfall 622 mm. Agricultural production is mainly cereals and to a lesser extent sheep (meat and cheese).

Siena - The area is located in the inland hills, with a mean elevation of 350 m. The phytoclimate is typical of xerophilous deciduous broadleaf vegetation (*Quercus cerris* and *Q. pubescens*). Mean annual temperature is 13.5°C and mean annual rainfall 792 mm. Agricultural production is mainly cereals, wine and oil; grazing is uncommon.

M. Amiata - The area is located in the montane belt, with a mean elevation of 800 m. The phytoclimate is typical of mesophilous deciduous broadleaf vegetation (*Castanea sativa, Fagus sylvatica*). Mean annual temperature is 9.8°C and mean annual rainfall 1554 mm. Agricultural production is mainly cereals with some sheep grazing.

Materials and Methods

Lichens were sampled on 10 oak trees (*Quercus pubescens*), five in agricultural sites and five in sites not farmed or grazed in the last 15 years, in each of the three areas surveyed, in May and June 1995. *Q. pubescens* was selected owing to its wide distribution in the three study areas. In order to minimize variations in epiphytic communities, trees were deemed suitable if they were free-standing, had a trunk circumference at breast height of at least 70 cm and an inclination of less than 10°.

The diversity of epiphytic lichen communities was surveyed in terms of the frequency of each species. Frequency was measured at chest height using a 30x50 cm grid, divided into 10 units of 10x15 cm (frequency = the number of grid units in which the species occurred). Sampling size was judged satisfactory since a further increase in the number of trees sampled did not result in a significant ($p<0.05$) increase in the number of species recorded.

Pieces of bark were collected from each tree sampled for pH and buffer capacity (β) measurements. In the laboratory, the bark was first freed of lichens, mosses and extraneous matter. For pH analysis, 0.3 g of the surface 2 mm were ground, soaked in vials with 10 ml deionised water and shaken for 8 h (Farmer et al. 1990; Johnsen & Sochting 1973; Watson et al. 1988); pH was measured directly in the solution using a pH-meter. To measure the buffer capacity of bark, 0.5 ml of 1N NaOH were added to 8 ml of bark powder suspension in deionised water and the solution was shaken for 12-16 h (Johnsen & Sochting 1973); pH was then measured directly in the solution. The buffer capacity of the bark was calculated according to the formula $\beta = 0.001/\Delta pH$, suggested by Johnsen and Sochting (1973).

For the statistical analysis of the data, a rationale was adopted based on the assumption that if there are consistent differences between agricultural and non-agricultural sites and/or between areas with different climates, sufficient markedly to influence distinctively the lichen vegetation supported by oak trees, then a multivariate classification of the data should reveal two distinct clusters. Ward's method was chosen as clustering algorithm since it uses an analysis of variance approach to evaluate the distances between clusters, i.e. this method attempts to minimize the sum of squares of any two (hypothetical) clusters that can be formed at each step (Hartigan 1975), and proved to give good results with biological data (Wishart 1987). For floristic analysis the percent disagreement was chosen as distance function, since it is particularly useful when the variables are categorical in nature as in the case of frequency data (Anderberg 1973). The significance of differences was tested by the Kolmogorov-Smirnov two-sample test and discriminant analysis.

Results

Table 1 shows the frequency values of each lichen species found during the survey. From a phytosociological point of view, the epiphytic lichen vegetation mainly consisted of species having their ecological optimum within nitrophytic, photophytic and xerophytic *Xanthorion* communities (Barkman 1958).

Figure 1 shows the results of cluster analysis applied to the raw data of Table 1. The dendrogram displays three main clusters, each mostly gathering samples from the same area, irrespective of agricultural exploitation. No strong

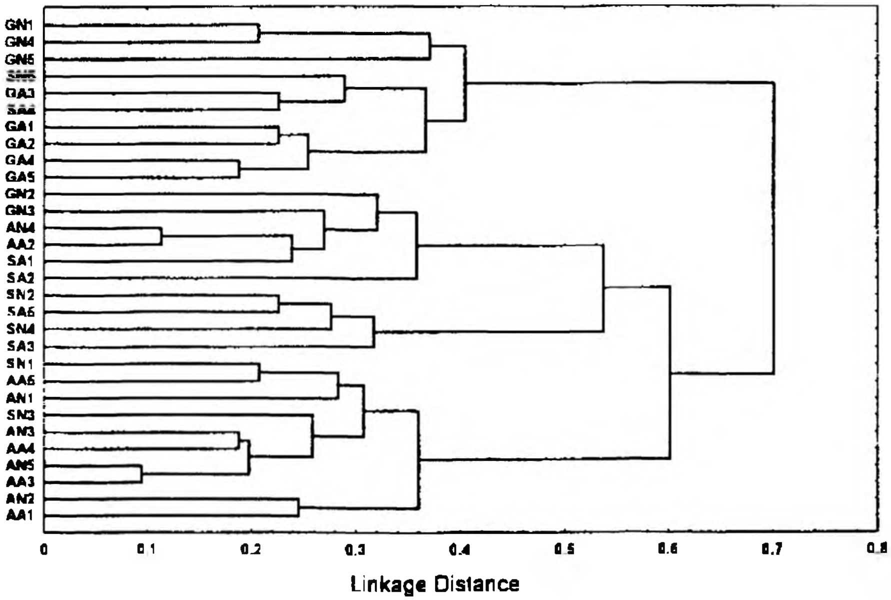

Fig. 1. Dendrogram showing the results of cluster analysis applied to the frequency data of Table 1. Labels: first letter: area (G = Grosseto, S = Siena, A = Mt. Amiata), second letter: land use (N = non-agricultural, A = agricultural), number: sites as in Table 1.

Table 1. Frequencies of all lichen species found on the sampled trees. N = non-agricultural site, A = agricultural site. Nomenclature follows N i m i s (1993).

	Grosseto										Siena										Mt. Amiata									
	N1	N2	N3	N4	N5	A1	A2	A3	A4	A5	N1	N2	N3	N4	N5	A1	A2	A3	A4	A5	N1	N2	N3	N4	N5	A1	A2	A3	A4	A5
Tree height (m)	9	8	7	7	7	9	8	8	9	8	12	11	11	8	10	7	8	10	10	10	9	12	9	8	15	11	8	15	6	7
Trunk circumference (cm)	145	130	120	140	140	110	155	120	175	170	195	210	170	120	80	85	150	155	145	70	120	80	80	100	210	95	90	220	160	230
Aspect on the trunk	NE	NW	NNW	NE	NW	ENE	W	ESE	E	E	NW	NE	W	E	N	W	W	NE	NE	W	N	NE	E	E	N	E	E	N	N	E
Bark pH	5.80	5.65	4.83	5.74	6.14	5.63	6.02	5.23	6.32	5.98	5.95	6.02	5.96	5.71	6.12	5.71	5.78	6.10	6.21	5.84	5.50	5.50	5.68	5.17	5.95	5.16	5.49	5.71	5.87	6.35
Bark buffering capacity (x10-4)	1.46	1.42	1.36	1.49	1.59	1.42	1.50	1.34	1.61	1.54	1.67	1.71	1.69	1.65	1.72	1.60	1.65	1.72	1.80	1.67	1.50	1.56	1.72	1.42	1.56	1.56	1.49	1.53	1.55	1.63
Acrocordia gemmata					2		1																							
Anaptychia ciliaris									2																					
Bacidia naegelii		4	3										3				7			3										
Bacidia rubella		6	1		9																									
Caloplaca cerina								1																						
Caloplaca ferruginea																					2	2				1				
Candelaria concolor		1						4							8	10	7	10		10	9						9			
Candelariella reflexa			7				1		3								1													
Candelariella xanthostigma										2							2			3									8	2
Collema multipunctatum				1																										
Collema subflaccidum				1	10				3		2																			4
Diploicia canescens															1	3														
Haematomma ochroleucum		10	5																											
Hyperphyscia adglutinata	1		10	1		10	10	3	10	10			10			1	2	7	4											
Lecania cyrtella						1																								
Lecanora carpinea																								3		2	2			
Lecanora chlarotera		10	3													1			4		4	2		10		3	7			
Lecanora horiza		3	4											4	3			2	1											
Lecidella elaeochroma		10	10										3	3		10	10			3		8		10		8	10			
Lepraria sp.		1																				5								
Normandina pulchella												10		5				2		10										
Ochrolechia turneri				2	5																									
Parmelia caperata	2	1		4								7	2	3		10	7	3		7	1	3	2		3	9		6	7	
Parmelia elegantula																					1									
Parmelia subaurifera																										10				
Parmelia subrudecta					2	10					1	7	1	9		5	4	10		10	6		2					6	6	
Parmelia sulcata																						8	5			10			1	
Parmelia tiliacea					1		1		2	1	9							5			7	2	6						10	2
Parmotrema chinense												8				2	1	3					5		4	3				
Pertusaria albescens	1										5	7									4									2
Pertusaria amara																2														
Pertusaria hymenea																									10				3	5
Pertusaria sp.														3																
Phaeophyscia cernohorskyi							10		1	2					3															
Phaeophyscia hirsuta					5	7		10	10	4								3	10											
Phaeophyscia orbicularis					1							3						5	5											
Phlyctis argena														2																
Physcia adscendens	7	10	10	9	7	8	8	10	10	10	1	10		10	6	10	10	10	10	10	2		5	9			10			
Physcia aipolia	2			7		10		10			7	2		2	10		1	2	5	4				1						
Physcia biziana																	1													
Physcia clementei														4	1			1	7	6										
Physcia semipinnata	2	8		2		4	8			3																				
Physcia stellaris																										2				
Physcia tenella															5															
Physconia distorta			1		7			4	8	4	10		1				2	10	6		9	4	10						4	10
Physconia grisea	2					3			4	4			5																	
Physconia perisidiosa				10	2		5	4				10	1	6	3			6												
Physconia servitii	6	1		2	6	10		2		2	6			4	10		1		6											
Physconia venusta											5		10												10			10		
Ramalina fraxinea																			1											
Ramalina sp.		1																												
Tephromela atra																						2								
Xanthoria parietina	6	5	10	7	2	10	10	10	10	10	6	3	9	6	10		4	8	10		6			2		1	7	10	2	5

differences were observed between the lichen flora of agricultural and non-agricultural sites, with only a few species showing a higher frequency distribution ($p<0.05$) in agricultural (*Candelariella xanthostigma, Hyperphyscia adglutinata, Phaeophyscia hirsuta*) or non-agricultural sites (*Pertusaria albescens*).

Floristic differences due to climate were much more evident (Table 1), with several species showing a clear preference ($p<0.05$) for a well defined area: *Phaeophyscia hirsuta* and *Physcia semipinnata* in the Grosseto area, *Parmelia subrudecta* in the Siena area and *Parmelia sulcata* on Mt. Amiata. Furthermore, other species (*Hyperphyscia adglutinata, Physcia adscendens, Physcia aipolia, Physconia perisidiosa, Physconia servitii*) were more frequent ($p<0.05$) in the Grosseto and Siena areas whereas *Parmotrema chinense* was more frequent ($p<0.05$) near Siena and on Mt. Amiata.

These results were confirmed by discriminant analysis (Fig. 2), which showed statistically significant differences (Wilk's Lambda = 0.076, $p<0.001$) using climate (area) as discriminant, and a lack of significance for agriculture.

PH and bark buffer capacity of the sampled trees were not found to be statistically significant discriminants, capable of explaining the above floristic results.

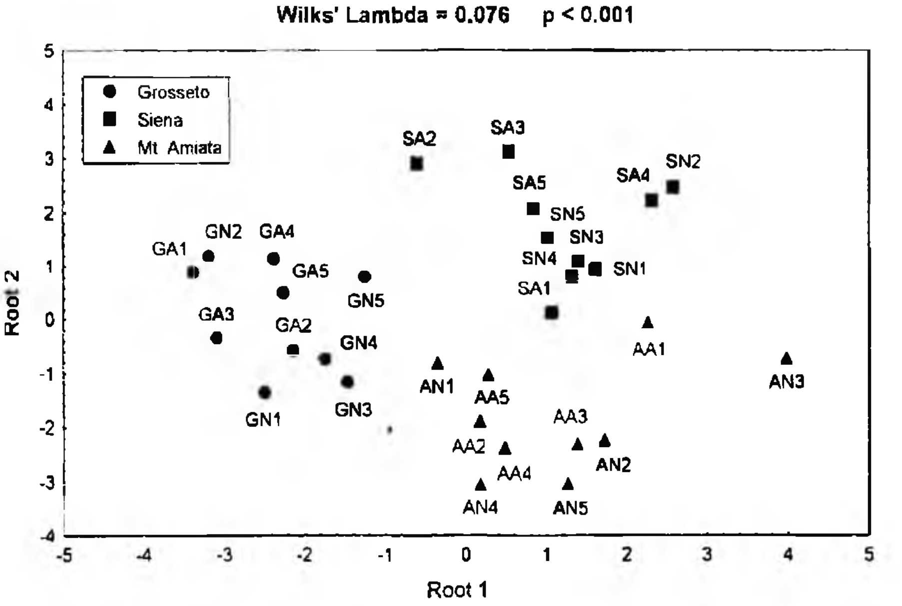

Fig. 2. Scatterplot showing the results of discriminant analysis applied to the frequency data of Table 1. Labels: first letter: area (G = Grosseto, S = Siena, A = Mt. Amiata), second letter: land use (N = non-agricultural, A = agricultural), number: sites as in Table 1.

Discussion

Many authors have explained the influence of agriculture on epiphytic lichen vegetation in terms of rising bark pH (De Bakker 1989, Van Dobben & Wamelink 1992, Van Dobben 1993, Van Herek 1993, Brown et al. 1995). However, the results of the present survey, as well as those reported by Loppi & De Dominicis (1996), did not find that bark pH was a discriminant parameter between agricultural and non-agricultural sites. Also the floristic assemblages were rather similar, except for a few species which were more frequent in agricultural areas (*Candelariella xanthostigma, Hyperphyscia adglutinata, Phaeophyscia hirsuta)*. These species are regarded as nitrophytic and neutro-basiphytic (Nimis 1993), indicating a secondary eutrophication of the bark due to agricultural activity (Nimis et al. 1991).

A clear distinction between the three study sites, capable of influencing the distribution of lichen species, emerged with respect to climate. The phytogeographical and ecological characteristics of the differential species of each area (*Phaeophyscia hirsuta, Physcia semipinnata, Parmelia subrudecta, Parmelia sulcata, Hyperphyscia adglutinata, Physcia adscendens, Physcia aipolia, Physconia perisidiosa, Physconia servitii, Parmotrema chinense)* are in line with the climatic features of the three areas (Nimis 1993, Loppi et al. 1997).

In the study area, lichen communities resulted that were influenced more by climate than agriculture, or at least, climatic parameters masked any effects of agriculture. This is probably due to the fact that in the Mediterranea area, light, dust and a more xeric microclimate probably have a greater influence on lichen distribution than agriculture (Barkman 1958, Pirintsos et al. 1996). However, it is worth noting that animal husbandry, which is a major source of atmospheric nitrogen, is not common in the study area.

According to Loppi & De Dominicis (1996) and Pirintsos et al. (in prep.), the higher frequency of "nitrophytic" species in agricultural areas can be explained by climatic (microclimatic) parameters. The present survey indicated that epiphytic lichens were chiefly distributed according to their ecological requirements with respect to climate. The preferential distribution of "nitrophytic" species in agricultural areas is also likely to be determined by similar requirements. In fact these species, besides being nitrophilous, are also xerophilous (Nimis 1993) and are probably promoted in agricultural sites by the drier microclimate determined by a greater abundance of wind-blown dust caused by agricultural activities.

Conclusions

In line with the results of Loppi & De Dominicis (1996), the present survey shows that the presence and frequency of "nitrophytic" lichen species in agricultural sites in the Mediterranean area is mainly due to the exacerbations of the xeric environment by ploughing which creates dust, rather than to nutrient enrichment of the habitat. In Mediterranean environments not subject to atmospheric pollution, climatic parameters seem therefore to be the main factor responsible for the distribution of lichen communities, as suggested by Loppi et al. (1997), whereas agricultural activities seem to have only an indirect effect.

It is rather evident that although the term "nitrophilous" is widely used in the lichenological literature, it should be used with care. Further floristic study is needed in agricultural areas for a better understanding of the effects of this complex human activity on lichens, with special reference to pesticides, fertilizers, animal husbandry and grazing (Alstrup 1993). As suggested by Pagès & Gomez-Bolea (1993), it is also important to compare the effects of agriculture on lichen communities of the Mediterranea area and those of central Europe. For this comparison, studies on the effects of climate and on the ecological basis of the lichen colonization of a given habitat are of basic importance.

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UČINCI KLIME I POLJOPRIVREDE NA VEGETACIJU EPIFITSKIH LIŠAJA U SREDOZEMLJU (TOSKANA, SREDIŠNJA ITALIJA)

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Vegetacija epifitskih lišaja na hrastu meduncu (*Quercus pubescens*) istraživana je u poljoprivrednim i nepoljoprivrednim područjima Toskane (središnja Italija) pomocu visinskog transekta, duž kojega vladaju različite klimatske prilike. Rezultati pokazuju da klimatske prilike više utječu na zajednice lišaja nego poljoprivreda. Prisutnost i učestalost "nitrofitskih" vrsta lišaja u poljoprivrednim područjima više ovise o sušnoj okolini, nego o obogaćenju staništa hranjivim tvarima.

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