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Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Pflanzenschutz im Forst, Braunschweig

Gypsy moth outbreaks in Germany and neighboring countries

Schwammspinner-Massenvermehrung in Deutschland und seinen Nachbarländern

Alfred Wulf und Elke Graser

Abstract

In the early 1990s, Germany and some neighboring countries suffered the first pandemic outbreak of gypsy moth *(Lymantria dispar)* observed in central Europe. The extent of the outbreak is reported and information on the area of damage and control measures is given. The climatic circumstances and the introduction of Asian strains of gypsy moth are discussed as possible causes for the outbreaks. From current research results, there is no indication that foreign strains of the pest had an important influence on the recently observed population dynamics.

Key words: *Lymantria dispar,* gypsy moth outbreaks, strain variation, climatic influence, forest damage

Zusammenfassung

Von Anfang bis Mitte der 90er Jahre wurde Zentral-Europa von der ersten pandemischen Massenvermehrung des Schwammspinners *(Lymantria dispar)* heimgesucht. Über das Ausmaß der Kalamität, über Schadensumfang und Bekämpfungsmaßnahmen in Deutschland und seinen Nachbarländern wird berichtet. Klimatische Umstände und das Eindringen asiatischer Schwammspinner-Herkünfte werden als Begründung der Massenvermehrung diskutiert, wobei derzeit keine gesicherten Hinweise gesehen werden, daß fremde Rassen des Schmetterlings einen besonderen Einfluß auf die populationsdynamischen Abläufe ausgeübt haben.

Stichwörter: *Lymantria dispar,* Schwammspinner-Massenvermehrung, Rassendifferenzierung, Klimaeinfluß, Waldschäden

Introduction

From 1991 to 1995, the most severe epidemic of gypsy moth *(Lymantria dispar)* ever observed in central Europe took place. The centre of infestation was south-west Germany, but some surrounding countries were affected as well. In this part of Europe, the native insect caused hitherto unknown defoliation of forests and the destruction of plants, and the caterpillar invasion even extended into urban areas. Therefore, control measures became necessary. The extent of the recent outbreaks, the amount of damage they caused, the methods used for control and the possible causes of this unusual epidemic are the subject of the following contribution.

Biology of the Gypsy Moth

The distribution area of *Lymantria dispar* extends from England in the west to Japan in the east. In Europe, the species is found from a latitude of 60° N in the middle of Scandinavia to 35° N on the Mediterranean coast. *Lymantria dispar* thus occurs from the vegetation zones of temperate deciduous forests to the Mediterranean scrub land. Since its accidental introduction to the east coast of North America in 1869 (FORBUSH and FERNALD, 1896), the gypsy moth has become established there and is currently still spreading westwards, having nearly reached the middle of the continent.

In line with its huge distribution area, *L. dispar* is one of the most polyphagous insects, possessing an extremely wide range of host plants. Although it prefers oak *(Quercus)* species, followed in preference by hornbeam *(Carpinus)*, beech *(Fagus)* and chestnut *(Castanea)*, it also feeds on several other deciduous trees *(Betula, Populus, Salix, Acer, Tilia, Ulmus, Alnus)*, even accepting larch *(Larix)* if no other plants are available.

In Europe the damage caused by gypsy moth generally increases from west to east and from north to south. The area that suffers most is the Balkan Peninsula, where severe outbreaks and defoliation of forest trees occur over thousands of hectares every 7 – 8 years, lasting about 4 years per outbreak. In the western parts of Europe, the intervals between outbreaks and their duration are longer. On the Iberian Peninsula, in contrast, both the period between outbreaks and their duration is usually more than 10 years. The concentration of the mass development in south-east and southern Europe is caused primarily by the climate and by the affinity of the insect to warmth and drought (SCHWENKE, 1978). In central Europe, only a few local outbreaks were reported up to 1993.

Outbreaks in Central Europe

In 1995 a conference of the European and Mediterranean Plant Protection Organization (EPPO) reflecting the gypsy moth situation was held in Poznan (ROY et al., 1995). Next to Germany, **France** has suffered most from the current outbreaks. In Alsace alone, 23,500 ha were defoliated in 1994 (LANDMANN and BARTHOD, 1996). Since the outbreak lasted longer in France than in other middle European countries, control measures using *Bacillus thuringiensis* were carried out in 1995 on 2,500 ha. In **Switzerland**, 2,000 ha composed mainly of chestnut trees south of the Alps were defoliated in 1992. After the breakdown of the insect population in 1993, the trees appear to have recovered without any treatment (ANON., 1995). **Austria** registered infestation on 1,500 ha in 1993, with severe defoliation affecting 400 ha of oak stands, but neither insecticide treatment nor important losses were reported (KREHAN, 1994). **Slovakia** and the **Czech Republic** had outbreaks in 1993/94 in oak forests in regions with a wine-growing climate, and treatments with *B. thuringiensis* or diflubenzuron insecticides were necessary. **Poland** was also affected during the recent outbreak period, but so far gypsy moth has not been a serious pest there. In Scandinavia, *L. dispar* specimens were collected in **Sweden** and perhaps in **Finland**, but never in **Norway**. The species is not considered to be a pest in the Nordic countries. In the **UK**, gypsy moth has been found several times recently, but is not regarded as a native species. An outbreak was discovered in a suburban district of London in 1995 and was treated with permethrin and *B. thuringiensis*. Eradication efforts continue in 1996.

In **Germany**, the southern and south-western areas which have a warm climate suitable for wine growing were at the centre of the recent gypsy moth outbreaks. Bavaria, Baden-Württemberg, Hessen and Rheinland Pfalz suffered most from the outbreaks (figure 1), while a second, eastern, focus became established in Sachsen and Brandenburg. First indications of an increasing gypsy moth population were observed in 1991, and one year later almost 2,000 ha were affected. In 1993, the first epidemic year, infestation covered 47,000 ha, and in 1994, before the natural population breakdown, the pest was present on about 80,000 ha.

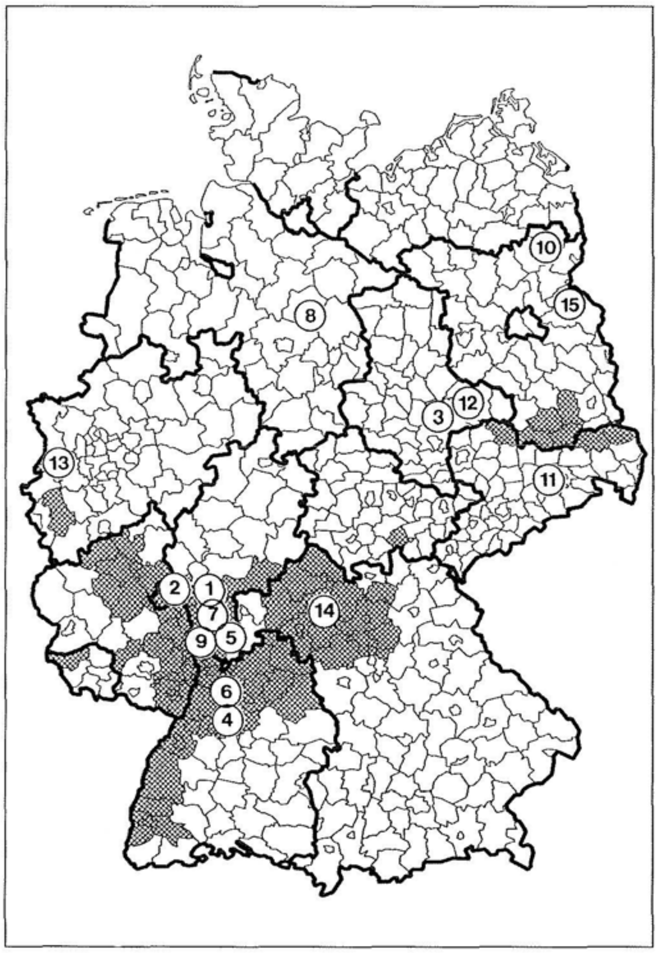


Figure 1. Area affected in Germany by gypsy moth in 1993. Counties with more than 10 ha of defoliation. Numbers denote sampling localities for cluster analysis of RAPD-PCR data (see figure 5).

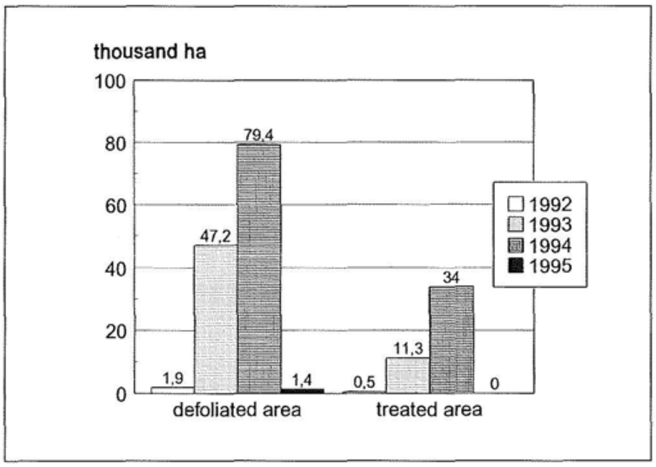


Figure 2. Relation between total outbreak area and area treated by control measures against gypsy moth in Germany.

Damage and Control

Since there was no previous experience with *L. dispar* as a pandemic pest in central Europe, the forest authorities had problems deciding whether protection measures were necessary, their extent, and means. The number of egg masses per tree in addition to age and vitality of the forest stands were considered as indicators for determining the necessity for control measures. In accordance with the present German situation on pesticide registration, *Bacillus thuringiensis* and diflubenzuron insecticides were chosen for treating forest stands. In 1993, c. 11,000 ha and in 1994 c. 34,000 ha were treated by helicopter (figure 2). The treated area increased from 24 % of the total infested area in 1993 to 43 % in 1994, one quarter being treated with *B. thuringiensis* and the rest with diflubenzuron. Due mainly to adverse weather conditions, some of the area treated in 1993 using *B. thuringiensis* failed to provide sufficient protection, but otherwise the control measures were largely successful. The experimental application of a virus pesticide showed satisfying results (LANGENBRUCH et al., 1996).

The planning and carrying out of protection measures were accompanied by many heated debates concerning environmental problems and side effects of pesticides. In order to provide a basis for objective discussions, two conferences on the subject were organized by the Federal Biological Research Centre for Agriculture and Forestry. The first was held in advance of the expected climax of the outbreak and was aimed at preparing the co-ordinated management of the outbreak (WULF and BERENDES, 1993). The second conference dealt with the epidemic retrospectively, in order to learn from past experience and try to find solutions for similar problems in the future (WULF and BERENDES, 1996).

One of the most intensely discussed problems dealt with the possible side effects of pesticide treatments to beneficial organisms and antagonists of gypsy moth. Fear was expressed that protection measures could interfere with the natural breakdown of gypsy moth populations and thus prolong the epidemic. The subsequent collapse of the pest population showed that there was no basis for this assumption. In Germany, in 1994 the breakdown of *L. dispar* populations occurred simultaneously over the whole infestated area, in treated forests as well as in non-treated ones, mostly caused by a virus disease of the caterpillars. No serious prolongation of the outbreak due to control measures has been observed or reported.

A second point of discussion was the necessity for protection measures in general. Based on experience from the Balkan region, where forests are adapted to surviving gypsy moth outbreaks, it was doubted that repeated defoliation could really mean severe damage to deciduous trees in Germany. However, results show that treatment was mostly justified, since individual trees and even large areas of forest can be killed. Severe losses and damage especially to some oak forests have been reported (LOBINGER and SKATULLA, 1996; WEZEL, 1996). One of the most impressive examples was demonstrated by DELB (1996) for the Bienwald region in Rheinland Pfalz, where circumstances led to the extensive, sudden decline of oak trees on more than 500 ha following defoliation by caterpillars in 1994, while treated forests in the vicinity were able to survive without loss (figure 3). In some cases valuable forest stands where control meas-

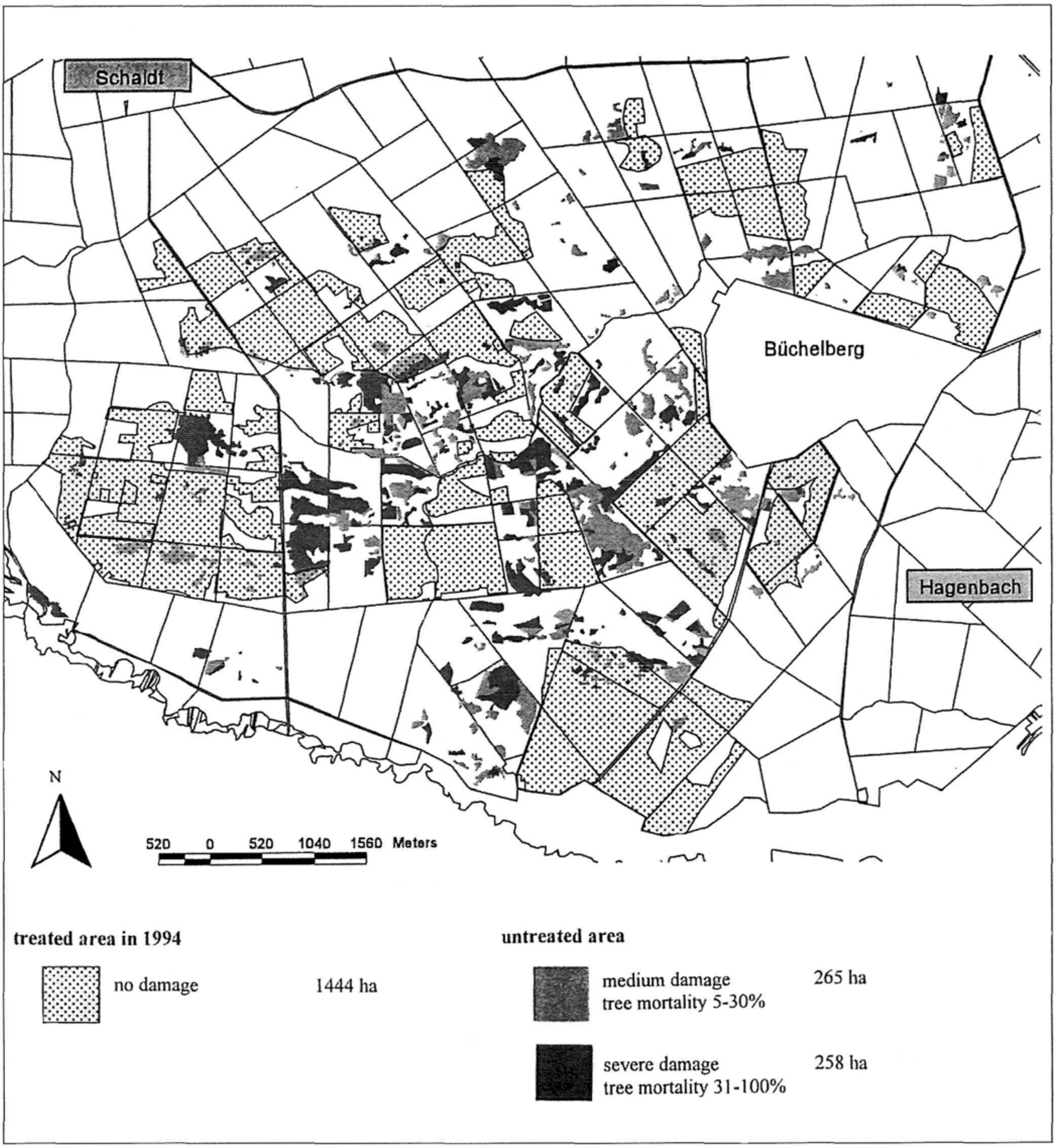


Figure 3. Effect of control measures against gypsy moth in the Bienwald district in 1994 on forest health in the following year (after DELB, 1996).

ures were rejected for environmental reasons were destroyed or much altered in their structure and species composition. Much research has been done on the side effects of forest protection products on non-target species, but in spite of the many interesting results yielded by these efforts there can be no doubt that the decline or even death of a forest is a much more lasting ecological loss for a given site than any limited influence of control measures on the invertebrate fauna.

Asian Gypsy Moth

One hypothesis for the recent unusual outbreaks is the introduction or migration of Asian gypsy moths to central Europe, because Asian strains are considered to be more aggressive. More support for this hypothesis was supplied by the observation of flying females in the outbreak area. In contrast to gypsy moths of European origin, the females of Asian strains are reported to be good flyers. The importance of knowing if central Europe was dealing with Asian gypsy moths increased dramatically when, in 1993, egg masses were discovered on military equipment being brought back to the USA from the German outbreak areas. As a result, quarantine measures for all transatlantic transports from contaminated regions were taken into consideration.

The lack of morphological characteristics for differentiation of *L. dispar* strains necessitated research based on molecular biology (BOGDANOWICZ et al., 1993). Preliminary trials comparing specimens collected in Germany with Asian material from Kazakhstan using the RAPD PCR (Random Amplified Polymorphic DNA-Polymerase Chain Reaction) technique showed certain differences (GRASER et al., 1995) but had to be extended by testing a larger number of Asian specimens. In addition, eight reference specimens from different localities in Russia, eastern China, south-eastern China and Japan were obtained (figure 4). For those and for several specimens collected from the German outbreak area (see figure 1), patterns of amplified DNA fragments were prepared in order to determine the genetic relationships between populations by means of cluster analysis.

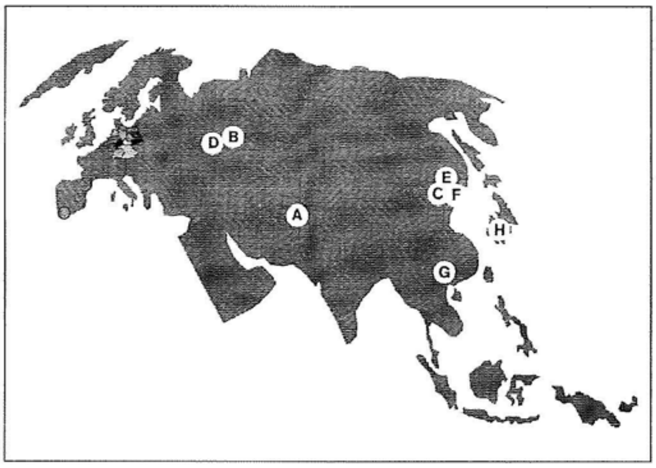


Figure 4. Origin of Asian gypsy moth samples for cluster analysis by RAPD-PCR.

Cluster analysis with RAPD patterns follow the same rules as any other taxonomic method: conclusions can be reinforced by increasing the number of characters. Therefore, the final results were corroborated by using data sets with an increasing number of characters for cluster analysis. Evaluations of 12–16 characters obtained with a single primer resulted in predominantly separate clustering of Asian and European populations, with only the occasional appearance of one to three Asian populations in the European branch of the dendrogram. The use of 97 characters obtained with seven primers resulted in the clear differentiation of Asian and European provenances. Moreover, with one exception, the geographical origin was reflected in the form of the dendrogram: Asian populations were clustered according to western and eastern provenances (figure 5).

Although results of further analyses show the occasional appearance of Asian specimens in the European branch of dendrograms (GRASER, 1996) and preliminary indications of the presence of certain Asian genes (REINEKE et al., 1996), there is no support for the idea of a major introduction of Asian *L. dispar* genotypes which could have influenced the severity of the recent gypsy moth outbreaks in Central Europe. As for the question of the females' flight capability for differentiating Asian and European strains, it seems very probable from recent observations that in European populations females have always possessed a certain degree of flight capability which can become more obvious during periods of high population density. Currently we are producing hybrids from European and Asian provenances in the laboratory. The offspring will be tested against forest insecticides based on *B. thuringiensis* to see if there are significant differences in susceptibility. This could provide an indication for aggression and danger caused by Asian gypsy moth.

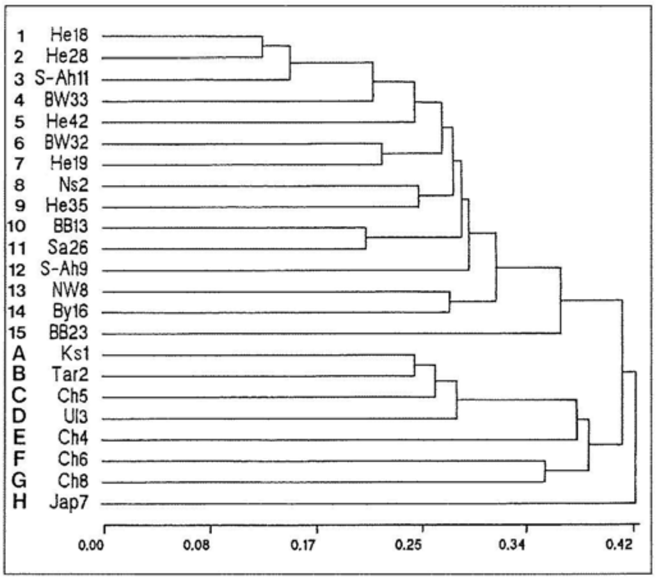
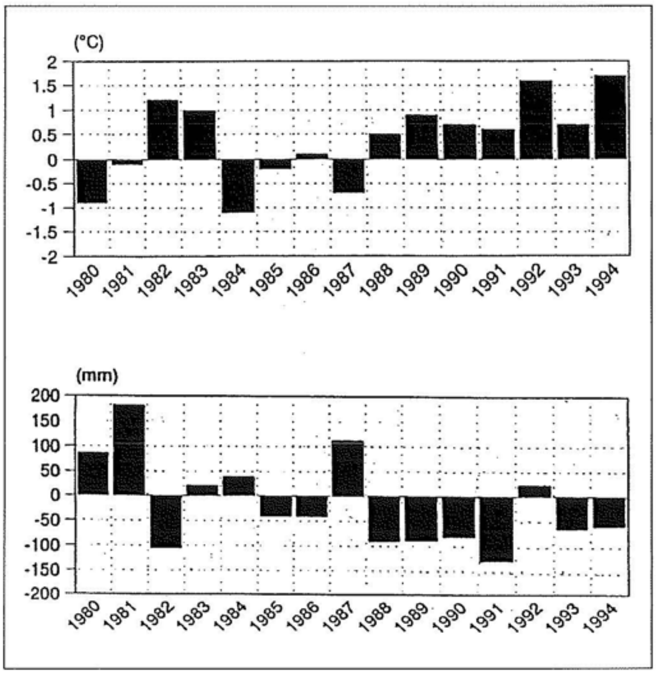


Figure 5. Dendrogram of RAPD-PCR cluster analysis for Asian and European strains of gypsy moth (for sampling localities, see figures 1 and 4).

Climatic influence

As a second hypothesis, climatic conditions could be an explanation for the recent extraordinary population development of gypsy moth in central Europe. Temperature and precipitation data during the growing season in south-west Germany shows the climate has substantially changed to favour *L. dispar* (figure 6). Warmth and drought have stressed trees for several years while favouring gypsy moth. (The copious fruiting of oak and beech in consecutive years is

Figure 6. Climatic data during the growth period (May to September) for Frankfurt, Germany. Deviation from the mean value of the years 1949–1994 for temperature (above) and precipitation (below). (Source: German Weather Service, Frankfurt)



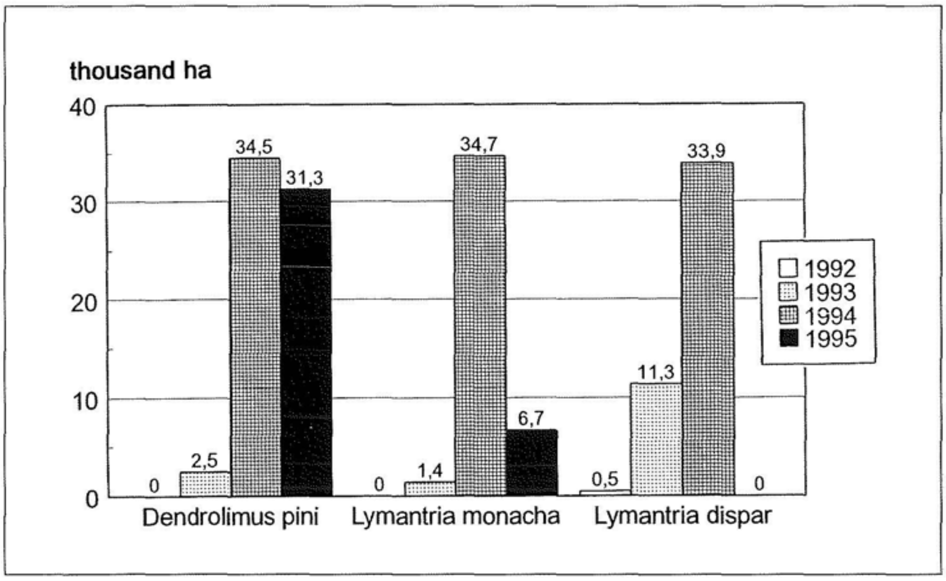


Figure 7. Area treated against defoliating caterpillars in German forests from 1992-1995.

indicative of such stress.) Such conditions are known to improve food quality, caterpillar and pupae development, copulating possibility and egg production (SCHWENKE, 1978). The fact that several different forest lepidoptera (e.g. *Lymantria monacha, Dendrolimus pini*) also developed outbreaks during the early 1990's, necessitating control measures comparable to gypsy moth treatments (figure 7), supports the idea that climatic factors were important. The conspicuous abundance of pests (e.g. *Phaenops cyanea*) and plant diseases (e.g. *Sphaeropsis sapinea*) in forests adapted to warm and arid conditions was noticeable during the period.

Conclusions

Climatic conditions provide a plausible explanation for the processes involved in the population dynamics of gypsy moth during the recent outbreaks. Although there may be a certain gradation of Asian genes from east to west, there is no indication of the recent introduction of an Asian form as a pest to Europe which could account for the outbreaks. The complete breakdown of the epidemic, as expected, and the realisation that females possessing flight capability tend to occur during periods of high population density support this point of view. In accordance with these conclusions, EPPO decided to reject quarantine regulatory action for the time being (ROY et al., 1995).

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Author's address: Priv.-Doz. Dr. Alfred Wulf, Biologische Bundesanstalt für Land- und Forstwirtschaft, Institut für Pflanzenschutz im Forst, Messeweg 11/12, D-38104 Braunschweig