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LABORATORY STUDIES ON DEVELOPMENT OF GYPSY MOTH, *LYMANTRIA DISPAR* (L.) (LEPIDOPTERA: LYMANTRIIDAE), LARVAE ON FOLIAGE OF GYMNOSPERMS

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Abstract

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The development of gypsy moth larvae was monitored in the laboratory on the foliage of 39 species belonging to 18 genera in the Araucaraceae, Cupressaceae, Ginkgoaceae, Pinaceae, Taxaceae, and Taxodiaceae. Larval survival through successive molts, time of larval development, live female pupal weights, and adult female production of ova were measured as indicators of host plant suitability for the gypsy moth. The criteria for distinguishing the most suitable hosts were as follows: (1) greater than 80% survival of first-instar larvae, (2) development to pupation in less than 41 days, (3) female pupal weights over 1099 mg, and (4) the production of more than 350 ova. The most suitable species were in the Pinaceae, in particular, *Cedrus deodara* (Roxb. ex Lamb.) G. Don, *Larix decidua* Mill., and *Picea pungens* Engelm. The least suitable species were in the Cupressaceae, Ginkgoaceae, and Taxaceae. First-, second-, and third-instar larvae often differed in their ability to survive on new foliage compared with foliage from the previous year. Overall, first-instar larvae successfully developed into adults on 20 of the species tested but second-instar larvae developed into adults on 29 of the species tested. First- through fourth- or fifth-instar larvae failed to develop into adults on eight of the species tested.

Résumé

On a étudié le développement des larves de la spongieuse au laboratoire sur du feuillage de 39 espèces appartenant à 18 genres des Araucaraceae, Cupressaceae, Ginkgoaceae, Pinaceae, Taxaceae et Taxodiaceae. La survie larvaire aux différentes mues, la durée du développement larvaire, le poids frais des pupes femelles et la production des oeufs, ont été mesurés comme indicateurs de la convenance de la plante pour la spongieuse. Les critères qui distinguent les hôtes les plus convenables étaient (1) une survie de 80% du premier stade larvaire, (2) moins de 41 jours de développement jusqu'à la pupaison, (3) le poids des pupes femelles excédant 1099 mg, et (4) la production de plus de 350 oeufs. Les espèces les plus convenables étaient des Pinaceae, en particulier *Cedrus deodara* (Roxb. ex Lamb.) G. Don, *Larix decidua Mill.*, et *Picea pungens* Engelm. Les espèces les moins convenables étaient des Cupressaceae, Ginkgoaceae, et Taxaceae. Les larves des premier, deuxième et troisième stades ont souvent montré différents niveaux de survie sur le feuillage nouveau, comparé au feuillage de l'année précédente. Globalement, les larves de premier stade se sont développées avec succès en adultes sur 20 des espèces testées, mais celles de deuxième stade ont produit des adultes sur 29 des espèces testées. Les larves des premier au quatrième ou au cinquième stade n'ont pas atteint le stade adulte sur huit des espèces testées.

Introduction

The gypsy moth, *Lymantria dispar* (L.), is notorious as a pest of broad-leaf trees and shrubs. Thus, a majority of the plants tested to determine foliage suitability for larval development have been woody angiosperms (Forbush and Fernald 1896; Mosher 1915; Kurir 1953; Edwards and Fusco 1979; Lechowicz and Mauffette 1986). However, each study did include a few gymnosperms and demonstrated that foliage from certain species of Coniferales may be very suitable for gypsy moth development.

The feeding studies that have monitored gypsy moth larvae on foliage (either on gymnosperms or angiosperms) include observations on developmental parameters such as larval survival, development time, pupal weight, and egg production (Barbosa 1978; Barbosa *et al.* 1983, 1986; Edwards and Fusco 1979; Hough and Pimentel 1978; Jobin 1981). Additional information is needed on the influence of foliage type, regarding maturity and species, on the feeding response, and development of larvae in each instar. In this study we conducted feeding tests with gypsy moth larvae using foliage from gymnosperm species of ornamental, commercial, and ecological importance in western North America.

Materials and Methods

Foliage was obtained from plants acquired from commercial nurseries in Oregon and California, the U.S. Forest Service, and outdoor gardens in the vicinity of Corvallis, OR. Those plants not grown in the Corvallis area were retained in their original potted condition and maintained at 10–21°C, 15L:9D photoperiod, and 40–65% RH to keep the leaves in a condition as similar as possible to that available when gypsy moth larvae would be developing in the field. Field testing of foliage was not possible because of quarantine regulations within the state of Oregon.

The tests were conducted during May and June in each of 3 years, 1984–1986. The tests used larvae which had eclosed in the laboratory from eggs collected in Oregon during the preceding winter of each year. The feeding tests were conducted by clipping a sprig of foliage from the plant and in most cases separating new and old foliage. New foliage was 1–4 weeks old, based on time of bud break; old foliage was 1 year old. In a few tests new and old foliage was not separated. The stem of the sprig was placed in a tube of water in a 0.5-L closed container with three gypsy moth larvae. This was replicated at least four times. Foliage was replaced at least every 2 days.

The protocol for testing successive larval instars was dependent on survival of larvae in the preceding instar. Larvae were initially tested as unfed first instars less than 8 h after eclosion from the egg. If these larvae survived through successive instars no additional larvae were used. If all larvae died before the next molt then <8-h-old second-instar larvae, reared on artificial diet, were tested. Similarly, if all second-instar larvae died before the next molt then <8-h-old third-instar larvae, reared on artificial diet, were used. A similar protocol was used for cases where third- and fourth-instar larvae died.

Observations were conducted on the effects of diet regarding certain fitness traits for larvae, pupae, and adults. If first- or second-instar larvae survived to the adult stage, larval developmental time at 23 ± 2°C, live weights of 48- to 60-h-old pupae, and ova production were recorded. Only full-sized ova, in the ovaries of 48- to 60-h-old adult females, were counted. These data were not recorded in tests when first- or second-instar larvae failed to survive because of the time spent on the artificial diet. The criteria for distinguishing the most suitable hosts were as follows: (1) greater than 80% survival of first-instar larvae, (2) development to pupation in less than 41 days, (3) female pupal weights over 1099 mg, and (4) the production of more than 350 ova.

Results and Discussion

First- through fourth- or fifth-instar larvae failed to molt to the next instar when provided foliage from eight of the species tested. None of the larvae in any instar were observed to feed on foliage of three of the species: *Taxus baccata* L., English yew; *Ginkgo biloba* L., maiden-hair tree; and *Podocarpus macrophylla maki* Sieb., shrubby yew pine. However, very minor feeding and frass production was observed for larvae on foliage of five of the species: *Araucaria araucana* (Mol.) K. Koch, monkey puzzle tree; *A. heterophylla* (Salisb.) Franco, Norfolk Island pine; *Juniperus californica* Carriere, California juniper; *Thuja plicata* Donn ex D. Don, western red cedar; and *Pinus sylvestris* L., Scotch

Table 1. Laboratory tests on the suitability of species and foliage of gymnosperms for the survival and development of female gypsy moth, Corvallis, OR, 1984–1986

Species*	Common name	Foliage type†	Larval survival‡		Development§		
			Instar	*n*,%	Time	Weight	Ova
CUPRESSACEAE							
Cupressocyparis leylandi	Leyland cypress	N+O	II	12,17	59+	551	145
PINACEAE							
Abies concolor	White fir	N	I	9,88	43	850	200
		O	I	9,88	43	1000	250
Abies grandis	Grand fir	N	II	7,71	54+	600	150
		O	II	7,71	54+	963	200
Abies holophylla		N	II	7,14	46+	156	—
		O	(III)	8,0	—	—	—
Abies procera	Noble fir	0	II	8,100	36+	242	65
Cedrus atlantica	Atlas cedar	N	I	6,83	50	955	290
Cedrus deodara	Deodar cedar	N	I	6,100	41	1430	455
		O	I	6,100	45	1784	727
Cedrus libani	Cedar of Lebanon	N	I	8,38	49	589	312
		O	(III)	7,0	—	—	—
Larix decidua	European larch	N	I	9,100	44	1280	336
Larix occidentalis	Western larch	N	I	7,100	46	743	216
Picea glauca conica	Dwarf Alberta spruce	N	II	6,67	49+	470	47
Picea pungens	Colorado spruce	N	I	8,100	34	1325	340
		O	II	9,100	35+	1253	357
Pinus contorta	Lodgepole pine	N	I	7,86	52	1545	649
		O	I	8,88	47	1261	503
Pinus halapensis	Aleppo pine	N	I	6,83	49	978	310
		O	I	6,83	49	1009	315
Pinus jeffreyi	Jeffrey pine	N	I	12,92	45	835	178
		O	II	6,100	44+	969	285
Pinus monophylla	Pinyon pine	N	I	8,75	54	493	87
		O	I	6,83	63	559	148
Pinus monticola	Western white pine	N+O	I	7,86	40	652	208
Pinus mugo mugo	Mugo pine	O	II	7,86	55+	1115	298
Pinus pinea	Italian stone pine	N	III	7,100	—	—	—
		O	II	7,86	40+	706	140
Pinus ponderosa	Ponderosa pine	N+O	I	25,80	46	1450	610
Pinus radiata	Monterey pine	N	I	8,100	47	856	163
		O	II	7,100	45+	885	290
Pinus sabiniana	Digger pine	N	II	12,92	34+	979	281
		O	II	12,92	34+	1012	253
Pinus thunbergii	Japanese black pine	N	(III)	6,100	—	—	—
		O	(III)	7,100	—	—	—
Pseudotsuga macrocarpa	Bigcone spruce	N+O	I	9,67	47	821	212
Pseudotsuga menziesii	Douglas fir	N+O	I	90,76	58	1247	615
Tsuga heterophylla	Western hemlock	N+O	I	60,40	57	1166	585
Tsuga mertensiana	Mountain hemlock	N+O	II	10,100	48+	504	118

Table 1. (*Concluded*)

Species*	Common name	Foliage type†	Larval survival‡		Development§		
			Instar	*n*,%	Time	Weight	Ova
TAXODIACEAE							
Cunninghamia lanceolata	Blue Chinese fir	N	V	6,0	—	—	—
		O	(III)	6,100	—	—	—
Metasequoia glyptostroboides	Dawn redwood	N	I	7,14	70	333	32
Sequoia sempervirens	Redwood	N	I	22,64	36	1253	650
		O	II	26,93	35+	841	270
Sequoiadendron gigantea	Giant sequoia	N+O	I	8,75	45+	885	367

*Pupal weight in *Abies holophylla* test was for a male.
†N = new, current season; O = old, previous season.
‡Instar development is noted for earliest survival to adult, ( ) indicates successive instars were not tested, *n* refers to number tested, % is the proportion of the number tested that survived to adult.
§ + indicates that time for previous instars on artificial diet not included.

pine. In general, the foliage from species in the Araucaraceae, Cupressaceae, Ginkgoaceae, and Taxaceae was not suitable for gypsy moth growth and development.

The survival of gypsy moth larvae on foliage of suitable gymnosperms was highly variable and depended on larval instar, foliage type, and species (Table 1). Of the 39 plant species tested, 20 were suitable for the development of a first-instar larva into an adult. Second-instar larvae developed into adults on 29 of the species, and third-instar larvae survived to adulthood on 31 of the species. Species of *Cedrus, Larix, Picea, Pinus, Pseudotsuga, Sequoia*, and *Tsuga* provided a diet most suitable for complete development from a first-instar larva to the adult stage. In general, the foliage from many species of Pinaceae and Taxodiaceae was suitable for larval survival of the gypsy moth.

The most suitable species were in the Pinaceae, in particular, *Cedrus deodara* (Roxb. ex Lamb.) G. Don, *Larix decidua* Mill., and *Picea pungens* Engelm. Average pupal weights resulting from first-instar development on foliage of these species ranged from 1253 to 1784 mg. A relative measure of comparison can be made with data from Barbosa *et al.* (1986) where larvae were fed foliage from certain trees and female pupal weights were as follows: 410 mg on red maple, *Acer rubrum* L.; 1030 mg on black oak, *Quercus velutina* Lam.; 1310 mg on willow oak, *Quercus phellos* L.; and 2380 mg on sweet gum, *Liquidambar styraciflura* L. The oaks and sweet gum were considered highly suitable hosts but the red maple was a poor host.

Foliage type was important in influencing the survival of larvae within and between instars. In the nine cases where foliage type (on the same plant species) affected survival through successive molts in different instars, seven resulted in the earlier instar surviving on the younger foliage and only two resulted in the earlier instar surviving on the older foliage. In tests where larvae of the same instar survived to adults, shorter developmental times, heavier pupae, and higher ova production were not always associated with feeding on one particular type of foliage. Similar variances in data were observed when larvae were fed foliage of broad-leaf evergreen trees (Miller *et al.* 1987).

No-choice feeding tests in the laboratory do not necessarily indicate the field-suitability of a plant species for development of the gypsy moth. Certain species, observed to be suitable in laboratory tests, may not be fed upon in an area subjected to a gypsy moth outbreak because (1) larvae may disperse and choose more preferred host plants; (2) the availability of foliage may not be timed to the presence of early-instar larvae; (3) the physical environment may change the ability of larvae to feed and survive on certain foliage (e.g. foliar nitrogen–water balance, leaf toughness).

However, feeding tests conducted in the laboratory did demonstrate relative degrees to which foliage from certain plant species may be suitable for development. Future studies are needed to determine host suitability in the field, quantity of foliage consumed by larvae, and the influence of various allelochemicals found in gymnosperms on larval gypsy moth feeding. Finally, the responses of larval and adult gypsy moths to foliage of various gymnosperms during artificial or natural selection need to be studied.

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