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ESTABLISHMENT AND SURVIVAL OF EUROPEAN PINE SHOOT MOTH ON CONTAINER-GROWN 1-0 LODGEPOLE PINE: AN INTERIM REPORT

by
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INTERNAL REPORT BC-28

DEPARTMENT OF THE ENVIRONMENT
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INTRODUCTION

The European pine shoot moth, *Rhyacionia buoliana* (Schiffermuller) (Lepidoptera: Olethreutidae), has become an increasing problem since its appearance in coastal British Columbia in 1925 (McLaine 1926). It was detected in coastal Washington State in 1959 (PNFRES 1960), in Oregon in 1960 (PNFRES 1961), and in the Okanagan Valley in interior B.C. in 1961 (Silver and Ross 1962). It was already recognized as a serious menace to hard pines in North America because of severe plantation infestations in southern Ontario, the Lake States and eastward, which had developed since its discovery in New York in 1914 as an introduction from Europe (Busck 1914); soft pines are occasionally attacked. No adequate control has been found for *R. buoliana*, despite attempts with quarantines, chemicals, parasites and cultural practices. Studies in Ontario indicate that in eastern America *R. buoliana* is generally unsuccessful in areas that have winter temperatures below -20 F (Green 1962), but snow cover may protect the insect against considerably lower temperatures and permit an extended range, subject to weather conditions. The shoot moth seemingly prefers host species exotic to B. C., but it can flourish on native species, particularly those in locations other than natural. While not yet found on forest trees in B. C. or northwestern United States, *R. buoliana* projects as a potential threat to forestry because of the anticipated large increase in acreage of planted pine. It is still not known whether or not the insect could successfully adapt to the extensive natural stands of native lodgepole pine, *Pinus contorta* Douglas, and ponderosa pine, *P. ponderosa* Lawson.

Lodgepole pine is becoming an important nursery species for reforestation and, during recent years, large quantities of experimental seedlings have been grown. Most of the container nurseries are located in the lower Fraser Valley or on southern Vancouver Island, where *R. buoliana* has already become widely established on ornamental trees. With the advent of large-scale use of containerized stock, and its transfer to many areas essentially free of shoot moth, the possibilities for the dispersal and further establishment of the pest have increased tremendously. The insect could be successfully introduced from a single pair of larvae or pupae in plant stock, or even from one mated adult female. During the current season, more than five-million lodgepole seedlings were sent out from the B.C. Forest Container Nursery at Cloverdale. Quarantine regulations currently in force includes the fumigation of seedlings; not only is the procedure an important added cost to reforestation, but severe losses in damaged and killed seedlings are incurred.

Ordinarily the pine is seeded at the container nurseries during April and transferred to interior locations in either autumn or the following spring for spring planting. Thus container seedlings on the coast are vulnerable to possible shoot moth contamination only during their first summer when they are about 2 inches high, when moths are laying eggs. The purpose of this study is to find out: 1) whether *R. buoliana* females will successfully utilize young 1-0 lodgepole pine seedlings for oviposition, and 2) if the larvae can successfully feed, overwinter and mature on 1-0 seedlings under standard nursery conditions. If they can, protective measures should be taken so that the insect is not distributed to pest-free regions; if the moth cannot complete its life cycle under these conditions, such seedlings can be safely transported anywhere without concern for dispersal of *Rhyacionia*. Reports of larval survival on young seedlings are conflicting, and no published data of controlled experiments are available.

METHODS

Pine seedlings used in the study were handled in all respects to duplicate standard container nursery conditions. Similarly, the insects were not given improved or altered circumstances, beyond the necessity of confining adults in cages.

Seedling stock

Two varieties of lodgepole pine seed were used to determine whether possible differences in seedling development might influence *R. buoliana*. Interior seed of lodgepole pine, *P. contorta* var. *latifolia* Engelmann, came from Prince George: Pl 55, Bednesti, B.C.: 83G14/B3/55/2.7; coastal seed of shore pine, *P. contorta* var. *contorta*, originated from northern Vancouver Island: Duncan 1905, Northwest Bay, B.C.: 92F8/B2/905/0.3. Both seed lots had been stratified, and were soaked 24 hr in water before seeding on April 5. Seeds were sown in BC/CFS Styroblocks #2 (Matthews 1971), each styroblock with 192 cavities. Blocks were filled with #1 Cornell soil mix and kept damp at 70-75^{o} under continuous light from 6 am to 10 pm for seven days. Seedlings were thinned 1/cavity, and lightly covered with granite grit as the seed coats were shed. Three styroblocks were sown to each variety.

On April 29 the seedlings were moved to an outdoor shadehouse that supplied 20% shade. Water and nutrients were supplied via a top-watering irrigation system. High nitrogen fertilizer, 28-14-14 Plant Prod, was applied approximately twice weekly at a rate of 3 oz/ 100 gal. The styroblocks were cut into 24-cavity sections in early June, to facilitate future handling. Each container was color coded to separate the pine varieties, but there was no obvious distinction between the seedlings.

Rearing *Rhyacionia* material

Infested material was collected during late pupal stage to reduce rearing-mortality from humidity changes and handling. Upon arrival, the container bags were stored at relatively cool temperatures, approximately 55 F, to discourage untimely emergence; the pupae were then removed to rearing vials, 5 pupae/vial. Although removal of the pupae from the buds likely resulted in lower successful emergence (Pointing 1961), it greatly facilitated the observation, recording and handling of the adults that did emerge. The pupae were kept at approximately 72 F, 60% humidity, illuminated 14 hr/day. Fully developed adults were removed to breeding cages. Emergence dates varied between collections, but commenced June 16, peaked July 5, and had nearly ceased when rearing was discontinued July 15.

Mating

Several ways of arranging caged mating were employed:

1. Small, confining cages indoors, i.e., rearing vials with little ventilation.
2. Large, well-ventilated outdoor cages.
3. Large, well-ventilated indoor cages with controlled air flow.
4. Releasing virgin adults of both sexes directly into the tree cages.
5. Releasing only mated females in tree cages.

The third method was the most dependable; all available moths were put into large, well-ventilated indoor rearing cages, left overnight at room temperature (approx. 75 F), and then the females removed to the shadehouse tree cages. A critical factor was a minimum mating and oviposition temperature of 60 F.

Caging and maintaining insects and seedlings

Cages used were 12 x 12 x 18 inches, wood frame, cheesecloth covered, with a full-size clear plastic hinged door. Twenty cages were set up in another shadehouse, each with two block-sections of seedlings: one coast variety and one interior. This quantity was adequate for statistical analysis, and within the prospects of obtaining sufficient gravid females. This second shadehouse differed in that it was lightly roofed, giving greater shade and slightly restricted ventilation. Adults were added to each cage as they became available (5♂, 5♀) and after ten days, when most of the original moths were well past their prime, four or five additional adults of each sex were added to each cage. Oviposition and adult mortality-counts, with behavioral notes, were made daily for each styroblock-section and cage. Dead adults were removed; in most instances this occurred before the eggs hatched. Records were kept of larval progress and seedling condition and appearance. When larvae became more or less quiescently established in overwintering hibernacula, during late October, the block-sections were removed from the cages and put completely outdoors in an area well away from any other possible food source for the insects. Watering was continued when necessary between rainfalls and fertilizer gradually decreased, following the CFS nursery pattern (Matthews 1971).

RESULTS

R. buoliana rearing stock (Table I)

Material collected was in good condition. Larvae from the earliest collections were reared to pupae. Total adult emergence was 56%, with a sex ratio of about 5♂: 6♀. Mortality from parasitism was 9% (all hymenopterous, mostly ichneumonids), while mortality from miscellaneous causes was 35%, mostly derived from removal of the pupae from the buds, compounded by dehydration. Approximately half the stock was used for an associated study*. At the beginning of the experiment an unseasonable cool period considerably reduced positive results in outdoor cages.

Several species of associate insects with habits similar to R. buoliana were recovered from the mass collections, but none was of

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* "The possible preference by European pine shoot moth for coast or interior varieties of lodgepole pine", currently in progress at Victoria by the author.

apparent influence on the Rhyacionia population.

TABLE I

Rearing of R. buoliana breeding stock

No. specimens, mostly pupae, died of parasitism	162
No. specimens died misc. causes: mostly removal from shelter, dehydration	599
No. adult males emerged	455
No. adult females emerged	519
No. males tree-caged	214
No. females tree-caged	189

Pine seedlings and shoot moth oviposition (Table II)

Seed germination was approximately 95%, and thinned seedlings developed successfully with minor mortality. When moved from greenhouse to outdoor shadehouse, April 29, they were about ½-inch high, with well-developed whorls of secondary needles. When caged with R. buoliana, June 21, they averaged about 1½ inches high. A month later, during mid-July, when the larvae became active, the seedlings varied from 2-3 inches in height, with a small number showing lateral buds. Table II shows the total numbers of eggs laid on the seedlings. Most eggs were laid on the undersides of lower leaves, or on the lower stem. Nine of the containers did not have fertile eggs laid on the seedlings; some of the eggs laid in other containers were infertile.

TABLE II

Attraction of seedlings to ovipositing moths

	var. *contorta*	var. *latifolia*
No. block sections set up	20	20
No. block-sections infested	11	11
No. seedlings infested	54	56
No. eggs laid on seedlings	169	201
No. larvae from eggs	147	142

R. buoliana larval development (Table III)

Eggs hatched during mid-July and all larvae apparently accepted their surroundings and attempted to establish themselves. They moved into needle fascicles near the tips of the seedlings and spun up small shelters, where they commenced feeding on the nearest needle. Because the needles were small and immature, it was sometimes necessary for a larva to utilize two or three, instead of the usual one (Pointing 1963). It is likely that a few first-instar larvae were not located, but it is believed their quantity would approximate the mortality during first instar, so the resulting population totals for second instar would not be significantly out. When they changed to second instar, about the end of July, they usually webbed into terminal foliage, but then had to move down the stems as the tips withered.

Where there was more than one larva on a seedling most of them dispersed to other seedlings. In about two weeks, when more active feeding and boring commenced at third instar, many of the larvae had to adjust to rapidly changing conditions in the small soft plants: some larvae transferred to uninfested seedlings in the same block-section, the majority burrowed further down the seedling stems, others webbed up basal leaves for "outside" shelters, and some remained in the dead and dying tips. The latter seem to be still in good condition, if a little wizened; one disadvantage to their location is that the dead tips easily drop from the seedlings, and in most instances this separates the larvae from any future food. Larvae became less active through September. Some larvae died of exposure-starvation while trying to relocate; a few were eaten by earwigs; others died in the dessicated stems and tips, and some moulted to fourth instar. Most overwintering larvae appeared to be of standard size (Haynes and Butcher 1961), and in good condition. It was not possible to examine all the hibernacula because of disturbing live larvae.

TABLE III

R. *buoliana* larval development

	var. *contorta*	var. *latifolia*
No. larvae initially infesting seedling tips*	244	233
Instar II		
No. larvae moved to other seedlings	51	33
No. larvae remaining in dead tips	30	39
No. larvae in stems	138	112
No. larvae in basal foliage webs	48	46
No. larvae known dead (in dried tips, in stems, in webs, in transfer, etc.)	28	36
% larvae known dead**	13	15
Max % larvae attempting to overwinter	87	85

* After it was established that females would oviposit on seedlings, larvae were added from other sources to ensure adequate experimental stock.

** Mortality is probably higher; all insects in hibernacula could not be disturbed for inspection.

Effect of *R. buoliana* larvae on seedlings (Table IV)

Adult activities, and eggs *per se*, had no discernible effect on the seedlings. Few of the tips were directly affected by first-instar larvae. When larvae moulted to second instar and moved onto the stem of the seedling, most often webbing together the terminal leaves, the tips wilted within a few days and larvae moved down inside the stems. About mid-August, when the larvae began to reach third instar, many moved down outside to establish new shelters among the lower needle fascicles where they webbed two or three chewed leaves together against the stem and fed on both stem and foliage. Most of the larvae, however, continued burrowing inside the stems, which did not die as rapidly as the tips.

Tip-kill continued through August into September, although most of it was apparent within the first two weeks of third-instar larval attack. During August, the seedlings showed many dead or dying tips and presented a generally poor appearance, while the third-instar larvae were, for the most part, inside the stems. Occasionally a plant continued more or less uninterrupted progress by secondary terminal growth, but only rarely did damaged tips survive. As progressive seedling mortality occurred, and food-shelter sites became unsuitable through dessication, some larvae moved out of the dead tips and relocated on the tips of adjacent previously uninfested seedlings in the planter, where they bored in the stems. This resulted in additional tip-kill, although secondarily-infested seedlings were somewhat larger from the time of initial infestation, and relatively less of each individual plant was lost.

Larval feeding decreased through September, so that there was no further appreciable damage to the seedlings other than some earlier-injured plants failing. However, during September and October, more than one-third of the infested seedlings developed considerable lateral growth, usually from the lower half of the remaining stem, and appear to be flourishing, if slightly retarded and, in some instances, multi-branched. Larvae did not move into the lateral growth, which was relatively fresh and insubstantial, when they were seeking food and shelter. The few unattacked seedlings now average about 5 inches in height, which compares favorably with standard nursery stock. The infested seedlings, without obvious lateral development but still alive, are for the most part 2-3-inch stubs, containing quiescent overwintering larvae.

TABLE IV

Seedling mortality

	var. contorta	var latifolia
Total no. seedlings	258	259
No. seedlings primarily infested	191	178
No. larvae initially infesting seedlings (to 5/seedling)	244	233
No. seedlings infested secondarily*	51	33
% seedlings infested to November 1	93%	81%
No. tips killed	201	189
% infested seedlings killed, as November 1	47%	54%
% infested seedlings surviving by lateral growth, as November 1	34%	36%

* Larvae voluntarily transferred from original seedlings.

CONCLUSIONS

Final figures (Table II) indicate that caged female moths will definitely oviposit on young seedlings, and that they apparently have no marked preference for coast or interior varieties grown under similar conditions.

Although larval shelter is relatively meagre, it may be adequate for local normal winter conditions. Whether the seedling size will permit the early spring activities necessary for *R. buoliana* will have to be ascertained at that time.

When the young seedlings were first attacked, it seemed unlikely that they could survive but now, with more than half of them still living, there is no doubt that a good percentage will be able to successfully withstand the winter weather and continue satisfactory growth next year, subject to possible further activities of infesting shoot moth larvae (Table IV). Under natural circumstances, seedlings would never be exposed to such a concentrated attack, which was arranged for this study to ensure results.

PLANS FOR COMPLETING STUDY

Two questions still remain unanswered: will the larvae be able to survive winter weather in such small seedlings; and if they do, will they be able to complete their life cycle on the seedlings, or would it be possible for them to do so if they could transfer to larger plants, i.e., if nursery seedlings infested with late-instar larvae were moved to an area where larger trees were available?

Some block-sections have been moved to Duncan, Cloverdale and Chilliwack, where weather is more typical of B.C. Forest Service nursery sites. Observations and records will be continued, and additional photographs will be taken, if required. It is anticipated that final results should become available before July 1972, and a complete report will be written later in the year.

ACKNOWLEDGMENTS

This study could not have been made at this time but for the quick and generous cooperation of workers from local and other government establishments. Particular thanks are due to Mr. David McComb, U.S. Forest Service, Portland, Oregon, who organized and packed a massive collection of infested pine shoots. Mr. W.J.B. Devitt, B.C. Forest Service, Victoria, supplied pine seed. Local staff of Liaison, Development and Forestry Services were of considerable assistance with technical advice, and in the planting and maintenance of the seedlings, as was the greenhouse manager. Finally, my thanks to my supervisor, Mr. A.C. Molnar, who provided initial contacts and criticisms that saved valuable starting time for the project.

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