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Control of leafy spurge (*Euphorbia esula*) in Nebraska with the spurge hawkmoth (*Hyles euphorbiae*)[1]

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Abstract:

The feasibility of using the spurge hawkmoth (*Hyles euphorbiae* L., Lepidoptera: Sphingidae), as a biological control agent on leafy spurge (*Euphorbia esula* L.) was evaluated. Studies relating adult hawkmoth emergence from the pupal stage and spring growth of leafy spurge plants showed that the plants would provide food and oviposition sites for the insect. Two generations of the insect may occur each year. Winter temperatures at approximately 2.5 cm below the soil surface or in the litter would result in some mortality of hawkmoth pupae. Pupal release programs indicated that protection from insect and rodent predators was necessary for adult emergence to occur. Predator determination using ^{32}P indicated two specimens of *Calosoma calidum* Fab. and two specimens of *Formica subsericea* Say as possible predators. Predator determination using pitfall traps showed that several species listed by Canadian researchers as predators were present in leafy spurge stands in Nebraska. At this time it appears the spurge hawkmoth will not become a valuable biological control agent for leafy spurge in Nebraska.

Additional index words:

Biological control, release program.

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Introduction

Leafy spurge is a persistent deep-rooted perennial that reproduces by seed and roots. It is a serious pest in Canada, Wyoming, Montana, the Dakotas and western Minnesota. Leafy spurge is Montana's fastest spreading perennial weed and is estimated to infest about 40,000 ha. It was introduced into Nebraska before 1923 (5) and has spread to many Nebraska counties, particularly those in the north and cast. It is thought to infest 20,000 to 40,000 ha of roadsides, pasture land, rangeland and cropland[2]. In pastures it competes with forage grasses for light, water, nutrients, and space and may cause severe dermatitis or death if eaten by cattle.

Leafy spurge is difficult to control because of the high-energy reserves and reproductive capacity of the roots. The frequent cultivation or chemical treatment needed for control is often not economically feasible in pastures or rangeland.

In some areas of the United States, biological control is becoming an economical and effective tool for control of weeds. Efforts in Oregon to control tansy ragwort (*Senecio jacobaea* L.) with the cinnabar moth (*Tyria jacobaeae* L.) are showing a 25 to 30% forage increase on land where the weed has been brought under control (6). Within a decade after release of (*Chrysolina* spp.) and other biological control agents in California, Klamath weed (*Hypericum perforatum* L.) was reduced from a very serious pest to a roadside weed (4). Investigations by Surles *et al*. using a weevil (*Rhinocyllus conicus* Froel) as a biological control agent on musk thistle (*Carduus nutans* L.) showed successful insect establishment and high plant and head infestations (9). A later publication by Kok and Surles (7) shows a decrease in musk thistle plant density, viable seed and buds per plant due to the weevil. Hodgson and Rees report establishment of the weevil in Montana and a decrease in seed production of primary flowers (3).

H. euphorbiae was first introduced to North America by Canadian entomologists[3]. The use of the spurge hawkmoth for control of leafy spurge in Nebraska was considered because of its specificity for the target weed. In addition, it was felt that it would prove useful in areas that are inaccessible to ground or aerial application of herbicides or where use of these materials may damage surrounding vegetation.

The spurge hawkmoth is indigenous to southern and central Europe, northern India and central Asia (2). The adult, a nocturnal moth, has a wingspan of about 5 cm. Several days after the female adult deposits eggs on the spurge plants, very small larvae emerge, and over the following 2 to 3 weeks, proceed through five larval instars while consuming leafy spurge foliage. At the conclusion of the fifth instar the larva burrows into the soil or litter and pupates.

The objectives of this study were to determine whether or not the spurge hawkmoth could become established in Nebraska and to obtain information on predation in the release areas.

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[2] Nebraska Dep. Agric. Private communication.

[3] Harris, P. The biological control of leafy spurge in Proc. Leafy Spurge Symposium, June, 1979. Bismarck, North Dakota. Unnumbered publication, North Dakota Agric. Exp. Stn.

Materials and methods

Winter temperatures in soil and litter at Lincoln, Nebraska

Winter temperatures in soil and litter were recorded from November 17, 1976, through February 22, 1977, at Lincoln, Nebraska. Temperature probes were placed about 2.5 cm below the soil surface for the soil reading and between the soil litter and the soil surface for the litter reading.

Pupae emergence under two temperature regimes

Two growth chambers were used to determine the effect of temperature on emergence time of spurge hawkmoth adults from pupae. These tests were undertaken to determine whether two generations of the hawkmoth could be completed in Nebraska in one season and whether the life cycles of the insect and leafy spurge coincided well enough to allow establishment. Temperatures used were averages over a 20-year period for Lincoln, Nebraska. One growth chamber simulated temperatures from May through July 5. The second simulated temperatures from July 5 through August 31.

Pupae for the experiment were selected randomly from a shipment of pupae received from Ottawa, Canada several months earlier and kept at 5° C. One male and one female pupa were placed in each 54.6 × 56.6 × 12 cm screened cage in the growth chambers. The pupae rested on cotton moistened periodically with distilled water. Relative humidity in the chambers was kept at 50%. Growth chamber photoperiods simulated those of Lincoln, Nebraska.

Spring growth of leafy spurge at Lincoln, Nebraska

Observations were made near Lincoln to determine if spring growth of leafy spurge plants would coincide with the life cycle of the spurge hawkmoth. Growth of leafy spurge plants was recorded from the time the shoots emerged (March 7, 1977) until May 5, 1977. Two sites were selected in a spurge-infested pasture, one on a northwest facing slope and the other on a southeast facing slope. Three plots, 1 m^2, were established on each slope. Shoot numbers and heights were recorded and averaged on each site. Soil temperatures were recorded at approximately 2.5 cm below the soil surface.

Pupae release programs at Lincoln and O'Neill, Nebraska

Three types of pupae releases were made at each of two locations in 1975. The locations were near Lincoln in the southeastern portion of the state and near O'Neill in the northeastern portion. The release methods consisted of (a) a closed cage release, (b) an open-top cage release, and (c) a buried soil release. The closed cages were 1.8 m^2, constructed of 5.0 × 5.0 cm lumber and covered with 20 × 20 mesh (per 2.54 cm) nylon screen. The edges were buried and the door latched to prevent entry or exit from the cage. Pupae were placed in open cardboard 0.24 L containers and covered with a thin layer of moist soil. The containers were then placed on the ground inside the cage.

The open-top cages were constructed with 2.5 × 10.2 cm lumber and covered with 20 × 20 mesh screen. They were 102 cm high, 85 × 85 cm at the base and 30.5 × 30.5 cm at the top. Pupae were released in the same manner mentioned above. Four mouse traps were placed among the pupal containers.

The soil releases consisted of placing pupae approximately 2.5 cm below the soil surface or in the litter. Mouse traps were placed partially over the pupae.

During the summer of 1976 two variations of the open-top cage release were made near O'Neill, Nebraska. One consisted of placing one cardboard pupal container slightly above the water level in a 7.5 L bucket. This was accomplished by taping the container on top of a 450 g plant pot and placing the pot in the water. The second variation involved nailing a cardboard pupal container to a plot stake and leaving the container approximately 25 cm above ground level after the stake was pounded into the ground. Both methods were used inside the open-top cage that had its edges buried.

In experiments involving pupae releases it was possible to obtain information regarding causes for emergence failure. 'Viable' pupae had good color, texture, and response to gentle squeezing at termination of the experiment. Nonviable pupae had none of the above characteristics. Pupae of 'doubtful' viability possessed some of the viable characteristics but not all of them. Pupae or moths in the 'eaten' category were found with ants or other predators feeding on them or were in pieces. Moths in the 'partially emerged' category were found dead and partially emerged in the pupal case.

Release of hawkmoth larvae under a closed cage near Lincoln, Nebraska

On July 22, 1975, 148 third and fourth instar larvae and two pupae were released on spurge plants under a 3.7 × 7.3 × 1.8 m cage near Lincoln, Nebraska. The cage was covered with 20 × 20 mesh screen, the edges were buried and the door closed to prevent entry or exit from the cage except to make observations. The cage was checked periodically after release. The two pupae were placed approximately 2.5 cm under the soil surface in selected locations inside the cage.

Disappearance of hawkmoth larvae in the open pasture near O'Neill, Nebraska

In August of 1976 tests were conducted to investigate the disappearance of late third and early fourth instar larvae that were released earlier. Larvae were released in seven plots 1 m^2 in the open pasture with seven larvae released in five of the plots and eight larvae released in two of the plots. Larvae were placed on the plants and observed for a short while to make sure that they maintained a firm hold on the plant. They were observed daily.

Predator determination using ^{32}P at O'Neill, Nebraska

This experiment was done to determine predators of the spurge hawkmoth larvae. Foliated leafy spurge stems approximately 34 cm long were dipped into a tray containing 110 ml distilled water, 2 ml MON-0818 surfactant and 80 µCi ^{32}P- dipotassium phosphate (spec. act. of 500 µCi/mM). Stems were immersed in the solution for 5 minutes, then placed stem down in a water-filled test tube for drying after the excess solution had been allowed to drip back into the tray. This procedure was repeated three times for each stem. The stems were then tested for radioactivity with survey meter. Those showing activity were placed in a cage and third instar hawkmoth larvae were allowed to feed on them. Any larvae showing 8,000 to 18,000 cpm on the survey meter were considered suitable for release. Larvae selected for release were fed fresh leafy spurge for one day to clear the gut of radioactive fecal material.

Twenty radioactive larvae were released near O'Neill, Nebraska. Ten larvae were released in a wooded area and ten more in an open pasture. Both sites were infested with leafy spurge. The larvae were released within a square meter area and three pitfall traps (8.6 cm diameter) were placed in the ground with their tops at ground level surrounding each release. After 4 days the pitfall traps were collected and the insects contained were tested for radioactivity using a gas proportional counter. All insects in a particular pit trap were analyzed on the same day and adjustments were made to compensate for some pit traps being analyzed later than others. As each group of insects was analyzed, blank sample holders were interspersed among the samples to give an estimate of background activity. Each sample and blank was run through the counter four times and the average cpm was used. Standard deviations of the blanks were averaged and added to the mean cpm of the blanks for that day. Any insect sample that showed 150% or more of the mean blank plus the standard deviation of the blanks was considered to contain more than background radioactivity. These insects were sent to the United States Department of Agriculture Insect Identification and Beneficial Insect introduction Institute at Beltsville, Maryland for identification.

Predator determination with pitfall traps near Lincoln and West Point, Nebraska

In order to identify possible predators of the spurge hawkmoth in Nebraska, samples of insects found in leafy spurge stands at two locations were taken during the summer of 1977. The locations were near West Point in the northeastern portion of the state and near Lincoln in the southeastern portion of the state. Sampling at both locations was initiated in late June. Each location was sampled once per month until the end of September. Twelve pitfall traps (8.6 cm diameter) were randomly placed in the field at both locations in areas infested with leafy spurge. After 4 days the traps were collected, the insects separated, and those considered to be potential predators (ants, ground beetles, wasps and spiders) were labeled, placed in vials of 70-80% alcohol and sent to the United States Department of Agriculture Insect Identification and Beneficial Insect Introduction Institute at Beltsville, Maryland for identification. On return they were compared with lists of insects that Canadian researchers regard as predators of the spurge hawkmoth.

Results and discussion

Winter temperatures in soil and litter at Lincoln, Nebraska

In the litter daily low temperatures at Lincoln from November 17, 1976 to February 22, 1977 were generally within a few degrees of freezing. Of the low temperatures for a 24-hour period between these dates, 18% were between -13 and -7° C, 54% were between -6 and –2º C and 28% were between -1 and 7º C. The lowest recorded temperature was -13° C.

In the soil, daily low temperatures were slightly higher than those found in the litter. Fourteen percent were between -11 and -7º C, 31% were between -6 and -2º C, and 48% were between -1 and 7º C. The lowest recorded temperature was -11º C.

Data from Harris and Alex (2) show that mortality of hawkmoth pupae is between 40 and 64% in the -7 to -13º C range, 14 to 36% in the -2 and -6º C range and 0 to 14% in the -1 to 7º C range. Thus, pupation in the litter is likely to result in greater mortality than pupation in the soil. Since the winter of 1976-77 was a fairly normal one for Nebraska, one would not expect mortality due to winter temperatures to exceed 64%. It is possible that survivors could propagate a strain adapted to Nebraska's winter temperatures.

Table 1. Effects of temperature on emergence of spurge hawkmoth adults.

Simulated early (cool) temperature regime May 1 - July 5[1]		Simulated late (warm) temperature regime July 5 - Aug. 31[1]	
Emergence Date	Days required	Emergence Date	Days required
June 2	33	July 20	15
June 7	38	July 20	15
June 11	42	July 20	15
June 11	42	July 21	16
June 12	43	July 21	16
June 16	47	July 22	17
June 16	47	July 22	17
June 16	47	July 23	18
June 18	49	July 23	18
June 18	49	July 23	18
June 18	49	July 28	23
June 20	51	July 31	26
June 20	51	July 31	26
June 29	60	Aug. 2	27
Mean days required for emergence = 46		Mean days required for emergence = 19	

[1]Temperatures used in growth chambers for each day were 20 year averages for Lincoln, Nebraska. Pupae were placed n grwth chambers May 1 for the early temperatures regime and July 5 for the late temperature regime.

Pupae emergence under two temperature regimes

Table 1 shows the number of days required for emergence of spurge hawkmoth pupae under two temperature regimes. The pupae in the late (warm) temperature regime (July 5-August 31) emerged in less than half the number of days required by those in the early (cool) temperature regime (May 1-July 5). It should be noted that some latitude should be given to emergence dates. Because pupae in the wild would be exposed to slowly warming temperatures that occur before the starting dates of the experiments, their emergence dates may occur several days before that indicated by the experiment.

From the data we can conclude that it is possible for two generations of the hawkmoth to occur per year. One factor making this possible is the reduced time required for emergence of second generation adults due to high temperatures late in the summer. On the average, a generation will be completed in 72 days. However, Harris and Alex (2) report that at 32º C a generation may be completed in about 42 days.

Spring growth of leafy spurge at Lincoln, Nebraska

Leafy spurge stems on northwest and southeast slopes near Lincoln, Nebraska emerged from the soil on approximately March 7. Soil temperatures at 2.5 cm on both slopes were within 2º C at that time. Growth of stems on both slopes was uniform until about March 29 when stems on the northwest slope began to accelerate growth compared to those on the southeast slope. The northwest slope stems averaged 4.6 cm more growth than those on the southeast slope after March 29. As expected, soil temperatures appeared to have an effect on emergence of leafy spurge stems. The increase in growth of stems on the northwest slope beginning about March 25 may have been due to more rapid warming of the soil on the northwest slope during the day even though temperatures on the two slopes did not vary to any great degree. These temperature relationships may be explained by the orientation of the slopes. The northwest slope had more nearly direct insulation during the afternoon when air temperatures were also higher. Results from this experiment and from experiments on the effect of temperature on emergence time at Lincoln indicated that leafy spurge emerges early enough in the spring to provide oviposition sites and adequate food for the larvae.

Figure 1 shows average spring growth of leafy spurge on northwest and southeast facing slopes and average temperatures at the 2.5 cm depth.

Figure 2 shows the mean number of leafy spurge stems on northwest and southeast facing slopes. This figure shows that most of the stems that emerge will do so by approximately April 1. This is from 30-45 days before the hawkmoth adult would appear according to experiments involving temperature and emergence time of hawkmoth adults. Flowering of leafy spurge plants on both slopes began about April 12, which would be early enough to provide nectar for adult feeding.

Pupae release programs at Lincoln and O'Neill Nebraska

Of the three release methods used in 1975, the closed cage releases at both locations and the Lincoln open-top cage release showed the greatest hawkmoth adult emergence percentages (Tables 2 and 3). In the closed cages predators may have been prevented from reaching the pupae. Damage from those predators that may have been in the cage when it was placed on the site was probably low because at both the O'Neill and Lincoln locations pupae were observed to emerge relatively soon after the release was made.

There was no adult emergence from the O'Neill open-top cage and the O'Neill and Lincoln soil releases (Tables 2 and 3). Predation, perhaps by rodents, left nothing but small pieces of the pupal cases. Some of the adults may have emerged (in which case the pupal case would have been open at the anterior end only), but because all the pupal cases observed were in pieces this information was not available. The assumption is made that rodents would not bother to destroy already empty pupal cases.

The closed cage release at O'Neill was the only release where offspring were observed. Three fifth instar larvae were in the cage in late August, 1975. It is thought that these larvae had sufficient time to pupate and would emerge the following spring. Although ample snow cover was observed in the cage throughout the winter, no sign of emergence or reproduction was apparent in the cage in the spring or summer of 1976.

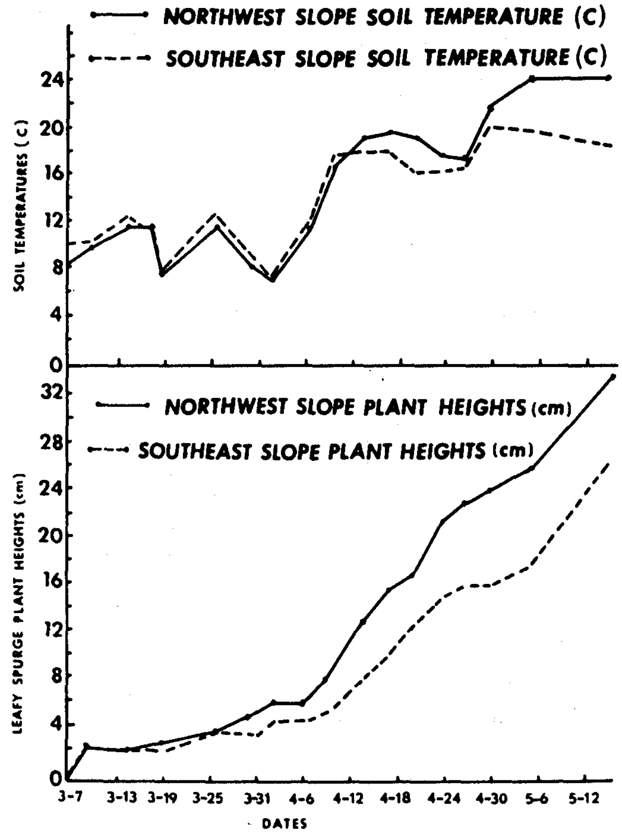

Figure 1. Growth of leafy spurge plants and soil temperatures 2.5 cm deep on northwest and southeast facing slopes at Lincoln, Nebraska in the spring.

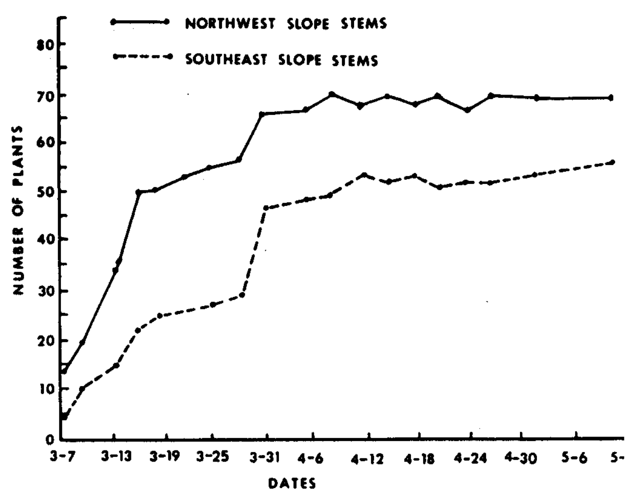

Figure 2. Mean number of leafy spurge stems on northwest and southeast facing slopes near Lincoln, Nebraska.

Table 2. Results of O'Neill pupae release program - 1975.

Observations	Release methods				
	Closed cage	1st open cage	1st soil	2nd open cage	2nd soil
Total pupae released	18	105	35	52	33
Number adults emerged	11	?	?	?	?
Number adults unemerged	7	?	?	1	?
Number live moths observed	4	0	0	0	0
Number larvae observed	3	0	0	0	0
Viable pupae unemerged	2	?	?	?	?
Non-viable pupae unemerged	3	?	?	?	?
Doubtful viability	2	?	?	1	?
Percent emergence	61	?	?	?	?
Pupae eaten	0	?	Assume 35	Assume 51	Assume 33
Moths eaten	0	0	0	0	0
Moths partially emerged	0	0	0	0	0

The mouse traps used in the soil release and the open-top cage release at O'Neill were usually found disarmed, overturned, or partially buried. One mouse, identified as *Peromyscus leucopus* or the white-footed mouse, was caught in the side of one of the pupal containers. Canadian entomologist's (1) report the white-footed mouse as a primary predator of caged larvae.

Table 3. Results of Lincoln pupae release program - 1975.

Observations	Release methods		
	Closed cage	Open cage	Soil
Total pupae released	30	243	160
Number emerged	9	47	?
Number unemerged	21	183	?
Number live moths observed	5	0	0
Number larvae observed	0	0	0
Viable pupae unemerged	3	54	?
Non-viable pupae unemerged	10	79	?
Doubtful viability	8	33	?
Percent emergence	30	19	?
Pupae eaten	0	16	Assume 160
Moths eaten	2	2	0
Moths partially emerged	0	1	0

In the summer of 1976 two more open-top cage release methods were evaluated (Table 4), i.e. bucket and stake. The water in the bucket serves as a moat to discourage predators. The stake method makes the pupae more difficult to find; however, insect predators and possibly predacious rodents could reach the pupae once found. These release methods showed more favorable results than previous methods and were more convenient. Some drawbacks are that water must be kept in the bucket and that moths may fall into the water and drown.

Leafy spurge stands within a 2 mile radius of the O'Neill and Lincoln sites were observed for presence of the spurge hawkmoth in 1976 and 1977 but no sign was found.

Table 4. Results of O'Neill bucket and stake pupae release program -1976.

	Release methods	
Observations	Bucket	Stake
Total pupae released	16	16
Number emerged	12	11
Number unemerged	4	5
Number live moths observed	2	0
Number larvae observed	0	0
Viable pupae unemerged	1	0
Non-viable pupae unemerged	3	4
Doubtful viability	0	1
Percent emergence	75	69
Pupae eaten	0	0
Moths eaten	0	0
Moths partially eaten	0	0

Release of hawkmoth larvae under a closed cage near Lincoln, Nebraska

Ants were seen feeding on several dead larvae and in one instance on a living larva after the release was made under the closed cage at Lincoln. On July 31, 1975 (9 days after the release) all but three larvae had disappeared, and these were gone 2 days later. Digging at random sites to determine whether or not the rapid disappearance of the larvae could be attributed to pupation did not reveal any papae. The cage was examined for adults, but none were found. The cage remained on the site from the summer of 1975 until spring, 1977. Periodic observations during that time showed no evidence of the hawkmoth under the cage.

In a similar experiment at Belleville, Ontario, Canada (2) of 360 larvae released in a cage on July 13, 1966 only 20.6% were recovered after 2 weeks; however, in another experiment by the Canadian workers started on August 31 recovery was 90% after 2 weeks. These researchers identified ants and the white-footed mouse as the primary predators. At

Lincoln and Bellville, it appears that predators had a direct effect on mortality of hawkmoth larvae. Since the large closed cage release at the O'Neill location in 1975 showed emergence, reproduction and progression of larvae through the fifth instar, apparently there may have been some difference in predator numbers or species between the Lincoln and O'Neill location at that time during the summer.

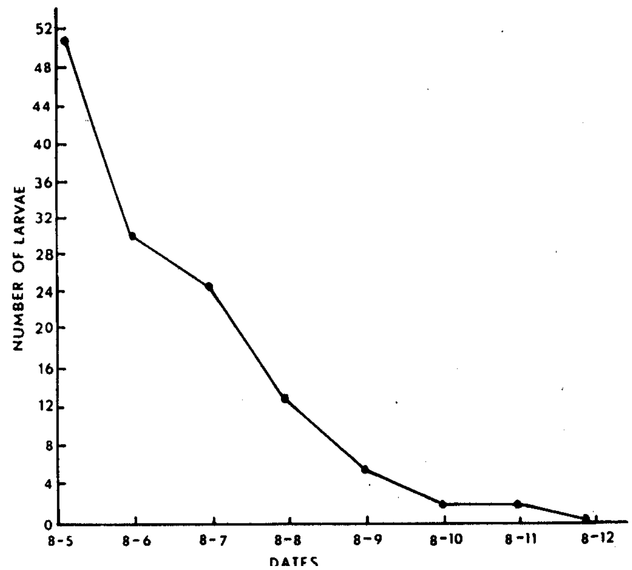

Figure 3. Disappearance of spurge hawkmoth larvae after release in an open pasture near O'Neill, Nebraska.

Disappearance of hawkmoth larvae in the open pasture near O'Neill, Nebraska

Because hawkmoth larvae will move little providing food is available, their rate of disappearance under field conditions can be determined (2). Of 51 total larvae released in the O'Neill plots on August 5, 1976, only two of the seven plots contained larvae on August 9. Three larvae were observed in each of these plots (Figure 3). By August 10 only one larvae in each plot was observed and by August 12 all of the larvae had disappeared. The area surrounding the plots was examined each day but no live larvae were seen. One larva from plot seven on August 6 and one larva in plots one and seven on August 7 were observed dead. The cause of death was not apparent.

Data from New (8) and from Lincoln studies agreed that hawkmoth larvae will normally live about 10 days after reaching the fourth instar. In view of the fact that 41% of the larvae in the plots disappeared after 1 day, 51% after 2 days, 75% after 3 days, and 88% after 4 days, predation could have been responsible. These results are similar to those of a Canadian study (2) where 95% mortality was reported 2 weeks after release of small hawkmoth larvae.

Predator determination with ^{32}P at O'Neill, Nebraska

Canadian research (2) shows that following the release of hawkmoth larvae made radioactive with ^{32}P, four species of carabids, *Calosoma calidum* Fab., *Pterostichus melanarius Ill., Amara obesa* Say and *Calathus gregarius* Say became radioactive. In addition, eight species of ants, *Myrmica areicana* Weber, *Lasius sp., Formica lasioides* Emery, *Formica pallidefulva nitidiventris* Emery, *Camponotus herculaeanus* (L.) *Formica obscuripes* Forel, *Formica haemorrboidalis* Emery, and *Crematogaster lineolata* (Say) became radioactive. *Calosoma calidum* Fab. and ants belonging to the genus *Formica* were also found to become radioactive in the O'Neill study (Table 5).

Table 5. Spurge hawkmoth predator determination with ^{32}P near O'Neill, Nebraska.

Analysis month/day	Type of release site	Number of samples	Number of samples considered above background
8/11	Open	56	2[a]
8/12	Open	38	
8/13	Open	37	
8/20	Wooded	39	1[b]
8/23	Wooded	65	1[c]
8/24	Wooded	44	
8/25	Wooded	36	

[a]Both specimens were *Calosoma calidum* Fab., 338 and 6,269 cpm.
[b]*Formica subsericae* Say, 256 cpm.
[c]*Formica subsericae* Say, 249 cpm.

Insects caught in the pit traps may have become radioactive in four ways: (a) feeding on dead radioactive hawkmoth larvae; (b) feeding on hawkmoth fecal matter that may have become radioactive; (c) feeding on exuviae or molted skin shed from the radioactive larvae; or (d) feeding on radioactive hawkmoth larvae that the insect actually killed. Since *C. calidum* and some *Formica* species have been shown to be predators in Canada and both had near to or over one and one-half times background radioactivity it is likely they are predators in Nebraska.

Predator determination with pitfall traps

Observations in leafy spurge stands near Lincoln and West Point, Nebraska showed that some insects considered to be predators on the spurge hawkmoth in Canada are present in leafy spurge stands in Nebraska. Near Lincoln, *Formica pallidifulva nitidiventris* Emery and *Amara* sp. were identified from pitfall trap collections. The West Point samples contained the carabids *Pterostichus chalcites* Say and *Calosoma calidum* Fab. and the ants *Myrmica americana* Weber and *Formica pallidefulva nitidiventris* Emery. *Crematogaster punctulata* Emery was collected at the Lincoln site. *C. lineolata* Say, was the species reported by Canadian researchers to be a hawkmoth predator.

Apparently if the spurge hawkmoth is to have any chance of becoming established in Nebraska, very high populations in the field will be needed to override the effects of predators. Large-scale field releases using the bucket and/or stake method may accomplish this. However, mortality of larvae and pupae may still be high due to predators and low winter temperatures. In addition, although the hawkmoth is capable of two defoliations of leafy spurge per year, it is questionable whether, this will significantly increase desirable forage grass production. In view of these problems it does not appear the spurge hawkmoth will be a successful biological control agent for leafy spurge in Nebraska.

Other biological control agents are presently being investigated for use on leafy spurge. A root borer, *Chamaesphecia tenthrediniformis* Denis and Schiffermuller, has been cleared for release in the United States and Canada and appears promising. Although the hawkmoth may not be effective alone, it may be valuable in combination with other biological control agents and such combinations should be investigated.

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