Cinnabar Moth as a Biological Control of Tansy Ragwort: Comparison of Population Dynamics in England and Oregon

by
Jerry L. Stimac and Dennis L. Isaacson[1]

ABSTRACT

The degree of control of tansy ragwort, *Senecio jacobaea,* by cinnabar moth, *Tyria jacobaeae,* is primarily a function of the plant response to defoliation and stability of the insect population. Cinnabar moth may have a greater potential for successful ragwort control in western Oregon than in England because in Oregon: (1) ragwort regrowth is rapid and includes both vegetative regeneration and secondary seed production, (2) major cinnabar moth mortality factors are density dependent, and (3) the parasite-predator complex has a lesser impact on cinnabar moth late larvae and pupae. A general discussion of the conditions necessary for successful biological control of tansy ragwort is presented—

After studying population dynamics of tansy ragwort (*Senecio jacobaea*) and cinnabar moth (*Tyria jacobaeae*) at Weeting Heath in Norfolk, England, Dempster (1975) concluded that three factors appear to be particularly important in determing the effect of the moth on the ragwort: climate, soil conditions, and vegetation structure. All three of these relate to the plant response to defoliation. Comparison of tansy ragwort and cinnabar moth population dynamics at Jordan, Oregon with those at Weeting Heath suggests that the stability of the cinnabar moth population is also important in determining the success of the moth as a biological control of the noxious weed.

At Weeting Heath in England, the cinnabar moth has not been successful in containing tansy ragwort at low densities (Figures 1-3). Both plant and insect populations have had high mean densities and high amplitude fluctuations (Figures 1-4). In contrast, at the Jordan site in Oregon the moth has been successful in reducing ragwort density and maintaining the weed at relatively low densities over a five year period (Stimac and Isaacson 1976). An explanation of the observed differences in herbivore and plant dynamics is indeed complex. It involves not only the response of ragwort to herbivore defoliation but also mortality factors influencing survival of the moth. Consequently, potential of cinnabar moth as a biological control for tansy ragwort is a function of environmental factors influencing growth and regrowth of ragwort as well as cinnabar moth mortality factors at particu-

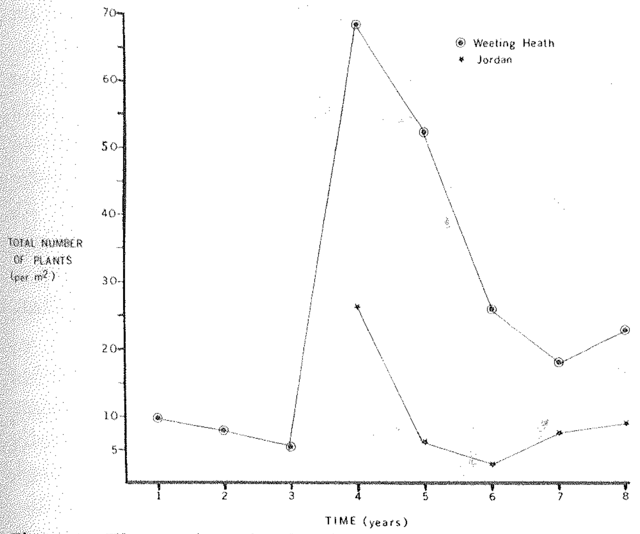

Figure 1. Fluctuations in density of spring tansy ragwort plants at Weeting Heath (1966-1973) and Jordan (1972-1976).

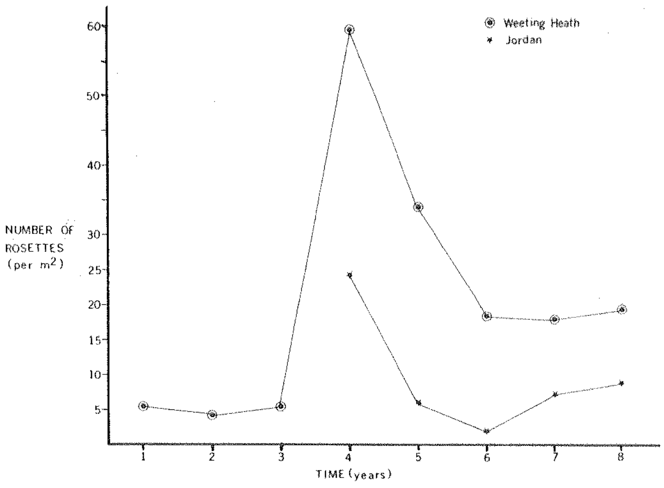

Figure 2. Fluctuations in density of spring tansy ragwort rosettes at Weeting Heath (1966-1973) and Jordan (1972-1976).

---

[1] Department of Entomology, Oregon State University and Oregon State Department of Agriculture.

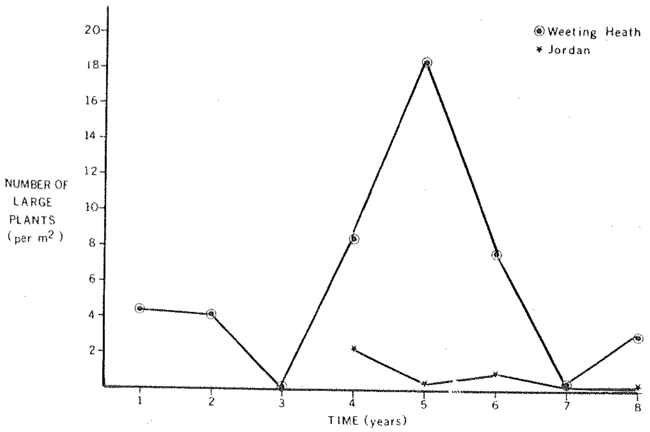

Figure 3. Fluctuations in density of large spring tansy ragwort plants at Weeting Heath (1966-1973) and Jordan (1970-1975).

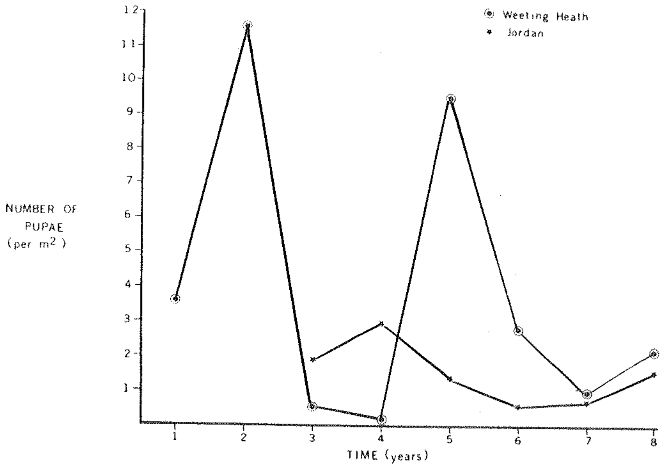

Figure 4. Fluctuations in late fall cinnabar moth pupal density at Weeting Heath (1966-1973) and Jordan (1970-1975).

lar sites. Examining these factors at the English and Oregon sites is therefore a logical starting point in attempting to explain the conditions under which cinnabar moth can be an effective biological control for tansy ragwort.

The Weeting Heath site in England is an open heath with relatively dry, sandy-chalky soil. Predominant vegetation includes clumps of sheep fescue (*Festuca ovina*) and bentgrass (*Agrostis* spp.). Mouse-ear hawkweed (*Hieracium pilosella*), stonecrop wallpepper (*Sedum acre*), little medic (*Medicago minima*), creeping thyme (*Thymus serpyllum*), and tansy ragwort (*Senecio jacobaea*) are frequent (Dempster 1971). The site is heavily grazed by rabbits, which reduces vegetation competing with tansy ragwort. Ragwort seed is produced primarily by single- stalked plants and most seed germinates in fall, but some does germinate in spring. When defoliated by cinnabar moth, mature ragwort plants do not usually produce a secondary seed crop by formation of axillary buds from defoliated flowering stalk. Vegetative regeneration from crowns and rootbuds of damaged rosettes is vigorous, especially in years when summers are wet. Roots of defoliated mature plants regenerate to a lesser extent than rosettes. The degree and timing of ragwort regeneration on the poor soil is dependent upon the wetness of the summer. Wet summers are, however, infrequent.

In contrast, the Jordan site in western Oregon is an unimproved pasture, which was logged during 1963-1965. Slash materials including stumps of dead and decaying wood are scattered over the site. Predominant plants are: blackberries (*Rubus* spp.), snowberry (*Symphoricarpos* sp.), various grasses (*Gramineae*), wild strawberry (*Fragaria* sp.), and tansy ragwort (*Senecio jacobaea*). Some small trees, mostly Douglas-fir (*Pseudotsuga menziesii*), are present (Isaacson 1973). The site is moderately to heavily grazed by cattle, which not only reduces the density of ragwort plant competitors but also produces hoof damage that provides bare patches of soil for the opportunistic ragwort to colonize. Cattle grazing in conjunction with more fertile soil and frequent wet summers (relative to Weeting Heath) allows the ragwort to respond differently to cinnabar moth defoliation.

Within the same season in which they are defoliated, mature plants often produce vegetative regrowth from rootstock and/or secondary seed from axillary buds. Rosettes produce vegetative regrowth from damaged crowns or rootstock, often less than two weeks following total defoliation. This rapid response to defoliation may prevent late instar cinnabar moth larvae from starving. Late larval consumption of regrowth allows many larvae to survive to pupation, insuring an increased complement of defoliator eggs the following year. At the same time, ragwort plants which are defoliated more than once in the same season have a lower survival or produce fewer viable seeds than those subjected to a single defoliation.

In addition to soil, climate, and vegetation structure differences in the Weeting Heath and Jordan systems, factors directly affecting cinnabar moth are also different. Dempster (1971, 1975) used k-factor analyses to show that pupal and fifth-instar mortalities contribute most to total annual mortality of cinnabar moth at Weeting Heath. He concluded that mortality in these stages were key factors in determining trends from year to year. Among the mortality factors of fifth-instar larvae, parasitism by the braconid, *Apanteles popularis,* acted in a density-independent manner to reduce numbers of fifth-instar larvae by as much as 25-35% (Dempster 1975). *Apanteles* is not a parasite of cinnabar moth larvae in the Jordan system. At Jordan larval mortality due to arthropod predators or starvation are key factors but both appear to be density dependent factors. Not enough data is yet avalaible to show this conclusively.

Another major difference between cinnabar moth populations at the English and Oregon sites is early pupal mortality inflicted by vertebrate predators. At Weeting Heath vertebrate predators reduce numbers of pupae by at least 50% every year and sometimes as much as 80-95%. The action of vertebrate predators was shown to be density-independent (Dempster 1975). Total pupal mortality at Jordan has not exceeded 40% over a five year period and was as low as 15% in at least one year (Stimac and Isaacson 1976). Such drastic differences in pupal mortalities at the two sites is probably related to availability of pupation sites where vertebrate predators have difficulty accessing over-wintering cinnabar moth pupae. At Weeting Heath cinnabar moth pupates in the surface layers of the soil, under small stones or among roots of vegetation (Dempster 1975). At Jordan pupae are heavily aggregated in and under bark of decaying tree stumps and woody slash not burned after logging (Isaacson 1973).

Parasitism by *Apanteles* and high pupal predation at Weeting Heath along with explosive plant regeneration during infrequent wet summers, are probably sufficient to qualitatively explain the differences between cinnabar moth and tansy ragwort population dynamics at Weeting Heath and Jordan. At Weeting Heath both parasitism and pupal predation are density-independent factors, which may act on the cinnabar moth population when levels of both plant and insect are low. If such a perturbation coincides by chance with a wet summer, the net result is that the insect population is depressed to a very low level, while the numbers of plants increase exponentially. This is precisely what happened at Weeting Heath in year three (see Figures 1, 4). Eventually, the number of moths increases due to relaxation of parasitism, pupal predation, and larval starvation mortalities. The ragwort population is again reduced to a low density until density-independent perturbations and a wet summer coincide again.

At Jordan the present absence of *Apanteles* and high pupal predation prevent such drastic perturbation of the cinnabar moth population. However, if these types of density-independent mortalities were present, one might expect to observe high amplitude fluctuations of ragwort numbers because regeneration of ragwort would be good in the absence of secondary defoliation by cinnabar moth.

Starvation is an important larval mortality factor at both Weeting Heath and Jordan. Yet starvation in the English system is more severe at low plant densities because as mentioned earlier, rapid regrowth of defoliated plants is less frequent than in the Oregon system. This raises a rather interesting point relating to evaluation of the potential of cinnabar moth to successfully control tansy ragwort. If the survival and ultimately the success of cinnabar moth is a function of: (1) site specific conditions, such as soil fertility, climate, and insect mortality factors and (2) plant response to defoliation, which is dependent upon site specific conditions, how can the insect ecologist cope with such complexity when attempting to evaluate the potential of cinnabar moth? One possibility is to use information from studies like those of Dempster (1975) and Isaacson (1973) to formulate conceptial and/or explicit mathematical simulation models.

Figure 5 is a conceptual model that might be used to qualitatively examine the potential of cinnabar moth in the two systems discussed in this paper. This model emphasizes that activities of cinnabar moth are dependent upon the status of the ragwort as well as site specific insect mortalities. Status of ragwort is dependent upon site specific growing conditions and cinnabar moth defoliation. If a quantitative assessment of the potential of cinnabar moth under specified sets of environmental conditions is desired, then the conceptual model must be translated into a more explicit mathematical form, a systems simulation model. Such a systems model is being constructed for cinnabar moth and tansy ragwort at Oregon State University (Stimac and Overton 1976).

When validated the systems model can be used to gain insight into specific sets of conditions under which cinnabar moth can control tansy ragwort at acceptable levels. Figure 6 shows how ragwort biomass at the Jordan site has fluctuated during 1971-1976. Trajectories A, B, and C are examples of what might happen to ragwort biomass in future years. The systems model may be used to deter-

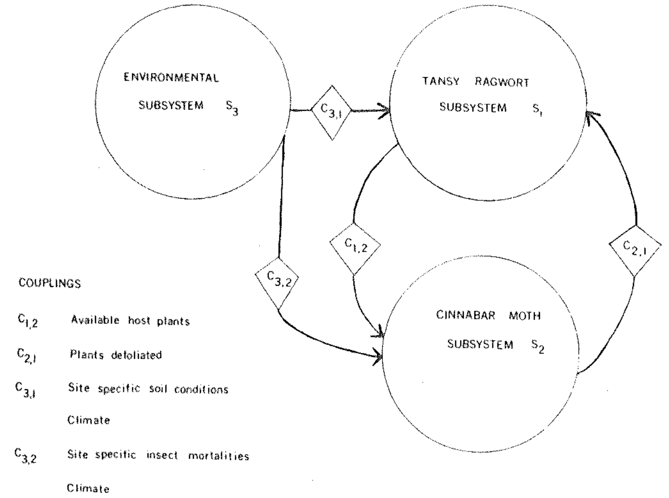

Figure 5. **Changes in spring tansy ragwort biomass at Jordan (1971-1976) and possible directions of change in future years.**

mine under what types of conditions the cinnabar moth population could be perturbed to allow ragwort biomass to assume the A trajectory, which represents loss of acceptable control. Trajectory B represents the present level of ragwort control by cinnabar moth. The systems model may be used to determine types and ranges of perturbations which cinnabar moth can absorb without serious increases in ragwort biomass. An example might be introduction of a hypothetical parasite or predator into the model. Trajectory C represents a lower and stable ragwort biomass. The systems model might be used to explore whether additional biological control agents might be used in conjunction with cinnabar moth to drive ragwort biomass down to trajectory C.

Dempster (1975) points out that often the cheapest way of evaluating the potential of a biological control agent has been to try it and see, yet much time and labor may be avoided by a prior knowledge of ways in which the populations interact. We hope that points raised in comparing the English and Oregon systems have made useful suggestions pertinent to cinnabar moth and tansy ragwort population interactions.

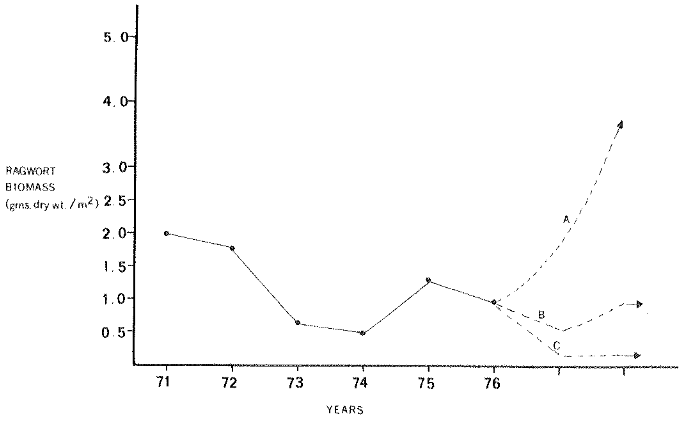

Figure 6. **A conceptual tansy ragwort-cinnabar moth population model showing important couplings among subsystems.**

REFERENCES

Dempster, J. P. 1971. The population ecology of the cinnabar moth, *Tyria jacobaeae* L. (Lepidoptera: Arctiidae). Oecologia 7: 26-67.

Dempster, J. P. 1975. Animal population ecology. Academic Press, London. pp. 63-75, 133-135.

Isaacson, D. L. 1973. A life table for the cinnabar moth, *Tyria jacobaeae*, in Oregon. Entomophaga 18(3): 291-303.

Stimac, J. L. and D. L. Isaacson. 1976. Population dynamics of tansy ragwort, *Senecio jacobaea*, and cinnabar moth, *Tyria jacobaeae*, in Oregon. Unpublished manuscript.

Stimac, J. L. and W. S. Overton. 1976. Construction of a tansy ragwort-cinnabar moth population system model. Presented at XV International Congress of Entomology, Washington, D. C.

EXPLANATORY NOTE

The following group of papers was presented as a symposium entitled "Biological Control of Tansy Ragwort", at the XV International Congress of Entomology, August 1976, Washington, D. C., U. S. A. Papers from such symposia were not printed in the Congress Proceedings; thus, since these papers all pertain to the subject of this symposium, they have been published here.