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OBSERVATIONS ON GERMINATION AND SEEDLING ESTABLISHMENT OF SENECIO ERUCIFOLIUS L. IN RELATION TO ITS NORTHERN BOUNDARY

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SUMMARY

The perennial species *Senecio erucifolius* L. is rare in the northern parts of The Netherlands. Its very local occurrence can hardly be explained by special environmental conditions.

Ripe achenes are not formed until the middle of September. The achenes show no dormancy, but the initial temperature requirements for germination are relatively high. According to germination experiments, germination may take place during the whole winter half of the year, but the seedlings are very susceptible to frost, which reduces establishment from seeds. The apparent absence of seedlings in the field confirms these conclusions.

1. INTRODUCTION

According to OBERDORFER (1962), the perennial species *Senecio erucifolius* L. has an eurasiatic-submediterranean distribution. The northernmost range of the species in N.W. Europe comprises S. Scotland (CLAPHAM et al. 1962; PERRING & WALTERS 1962) and the southern parts of Scandinavia (HULTEN 1950). In The Netherlands the species is common in the so-called Lime District of the province of Limburg and in the Fluviatile District (area of the rivers Rhine and Meuse), but it occurs only sporadically in the northern parts of the country. The very local presence of the species, sometimes in high densities, seems hardly explicable from special environmental conditions. The phenomenon was also noticed by RAABE (1969) at the North-Frisian island of Nordstrand (Western Germany). Thus, the distribution of *S. erucifolius* generally suggests that the species propagates by clonal multiplication and, in spite of the production of numerous fertile seeds, only incidentally by generative establishment. In the study of this phenomenon the following aspects are considered.

1. The species prefers moderately exploited grasslands on more or less calcareous soils with a heavy texture, especially on roadsides and slopes of dykes.

It is a character species of *Trifolion medii*, reaching optimum in the transitions between *Trifolion medii* and *Junco-menthetetum-longifoliae* (WESTHOFF & DEN HELD 1969). In a humid climate the habitats are generally characterized by dense canopies of mostly perennials. Nevertheless, gaps arise occasionally, *e.g.* by management practices or moles; also the verges of newly constructed roads and dykes form places apparently suited to establishment.

2. There is evidence that the dispersal of the achenes of this species is not very effective. Size and structure of achenes and pappus resemble those of the closely related *S. jacobaea* L. For the latter species POOLE & CAIRNS (1940) and SHELDON & BURROWS (1973) found wind dispersal of the achene-pappus less effective, especially in moist weather when the pappus opens incompletely. This will often be the case, as achenes of *S. erucifolius* only mature in autumn (see 3).
3. In the northern part of The Netherlands achenes of *S. erucifolius* do not mature until the middle of September. Therefore successful establishment can only take place if at least one of the following conditions is fulfilled (i) germination before winter is prevented by some dormancy mechanism, (ii) eventually emerging seedlings must be frost-tolerant.

To study these two aspects germination and sowing experiments were performed and the frost-tolerance of seedlings under artificial conditions was studied. In these experiments we compared *S. erucifolius* L. with the closely related species *S. jacobaea* L. and *S. aquaticus* Hill. (nomenclature according to HEUKELS & VAN OOSTSTROOM 1975).

2. MATERIALS AND METHODS

In 1972, 1973 and 1975 achenes of the three species were collected at different sites in The Netherlands (53°NL). Habitats are described in OTZEN (1977).

2.1. Germination experiments

Germination experiments were performed in petri-dishes of 8.5 cm ⌀ on filter paper, moistened with demineralized water. The dishes were placed in temperature-conditioned germination cabinets, illuminated with Philips TL 33 fluorescent tubes with a day/night cycle of 12 hours. Each treatment included 50 achenes in two-fold. Experimental conditions were:

A. Constant temperatures of 5, 10, 15, 20, 25 and 30°C. The germination experiments comprised freshly harvested achenes, collected in different years, tested soon after collection. Furthermore tests were conducted with samples stored at different conditions, including dry storage at 4 or 20°C or moist storage at 4°C between sheets of filter paper and combinations of these treatments.

Vigor ratings were calculated, according to THRONEBERRY & SMITH (1955): the number of germinated achenes counted each day was divided by the time in days after the start of the experiment. The values for each day were then totalled.

B. Low temperature, interrupted by a heat shock. The petri-dishes were placed in a germinator at 5°C. At intervals of 7 days (only once in a fortnight), the dishes were placed in an illuminated germinator at 25°C for 6 hours. The number of germinated achenes was counted weekly.

2.2. Sowing experiments

A. Garden. Plastic buckets with perforated bottoms (26 cm ⌀ and a height of 23 cm) were filled up with loamy sand, derived from the experimental garden at Haren. The sand, with an organic matter content of 3.5% and a pH (0.1 N KCl) of

4.5, was previously steam sterilized. In the buckets 4 × 250 achenes of each species were sown superficially. *S. erucifolius* was sown on 16th of September 1974, *S. aquaticus* and *S. jacobaea* were sown on October 17, 1974. All achenes were freshly harvested. The emerged seedlings were counted regularly, but were not marked individually.

B. Roadside. In the N.W. part of the province of Friesland a new road was constructed in 1975, running perpendicular to an existing road where numerous plants of *S. erucifolius* were found along a stretch of more than 100 meters on both sides of the junction. On the as yet bare verge of the new road freshly harvested achenes of *S. erucifolius* were sown superficially in rows at a distance of about 15 m from the old road, on the 9th and the 25th of October 1975, the 8th of March and the 7th of April 1976. At irregular times the rows and direct surroundings were inspected for the occurrence of *S. erucifolius.*

2.3. Determination of the frost-tolerance of seedlings

Plastic pots with an upper ⌀ of 10.5 cm were filled with 550 ml of a 1 : 1 mixture of coarse sand and enriched peat. Of each species 50 achenes (25 pots per species) were sown superficially at regular distances. The pots were kept at 5 °C in the dark for 3 weeks in order to synchronize the germination response. Subsequent germination at 20 °C and the usual day/night cycle for 4 days amounted to over 90 %.

The seedlings were then placed in a plant growth chamber with a day/night temperature of 8 h 10 °C / 16 h 5 °C, in order to promote the development of frost-hardiness. In the day-period the chamber was illuminated with fluorescent tubes (Philips TL MF 140 W/33 RS-double flux) and tungsten lamps (Philips Philinea 120 W) in a ratio of 12:1. The light intensity on the seedling level, in the range of 400–700 nm, was 210 $\mu E.m^{-2}.sec^{-1}$. The relative air humidity was about 70 %. Some achenes, germinating during the stay at 10/5°C, were removed from the experiment.

After 2, 3, 4, 5 and 6 weeks respectively 2 pots of each species were placed during 48 h, and another 2 pots during 72 h in a dark refrigerator at –5 °C, the pots being covered with plastic, in order to prevent desiccation. The pots were replaced in the growth chamber during the day-period, and remained covered for half an hour in order to prevent rapid thawing. At 24 days after the frost treatment the surviving seedlings were counted.

After 70 days in the growth chamber the aboveground parts of the untreated plants were harvested and dried to constant weight at 70 °C. The plants from the frost experiment were harvested 48 and 72 hours later respectively, in order to compensate for the arrest of growth.

3. RESULTS

3.1. Germination experiments

A. Effect of constant temperatures. The viability of freshly harvested achene

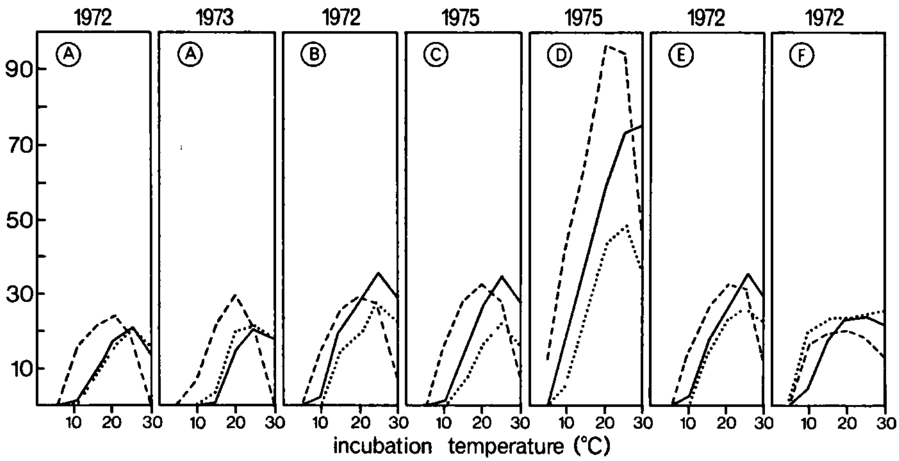

Fig. 1. Germination rate of achenes of three *Senecio* species expressed as vigor rating % (*viz*. text), as influenced by storage conditions and incubation temperature. ——— *S. aquaticus*, ----- *S. jacobaea*, ... *S. erucifolius*.

A: freshly harvested achenes. B: 3 months of dry storage at 20°C. C: 2 months of dry storage at 4°C. D: 3 months of moist storage at 4°C. E: 3 months of dry storage at 20°C, followed by 2 months of dry storage at 4°C. F: 3 months of dry storage at 20°C, followed by 1½ month of moist storage at 4°C.

samples generally ranged from 85 to 95%. This value was not significantly influenced by the way of storage.

The results of the germination experiments, expressed as vigor ratings, are summarized in *fig. 1*. It appears that *S. jacobaea* germinates most readily at 20°C and the other two species at 25°C. Dry storage irrespective of temperature, had no marked effect on subsequent germination. Moist storage at 4°C considerably enhanced the germination at all temperatures. Moist storage for 1½ month at 4°C, preceded by 3 months of dry storage at 20°C caused a decrease in temperature response, especially with *S. jacobaea* and *S. erucifolius*.

B. Effect of low temperature incubation, interrrupted by heat shocks. As demonstrated in *figs. 2* and *3*, *58% of the viable achenes of S. jacobaea* germinated at 5°C within 49 days. This is in marked contrast to *S. aquaticus* and *S. erucifolius* of which only 14 and 8% germinated respectively.

A single heat shock of 6 hours at 25°C, given after 1 week, accelerated the germination of *S. aquaticus* and *S. jacobaea*. *S. erucifolius* however, responded slightly to a heat shock only after 2 weeks.

After repeated heat shocks the three species completely germinated within 56 days, again however, the germination of *S. erucifolius* was accelerated to a lesser extent.

3.2. Sowing experiments

A. Garden. The course of germination, together with the daily maximum and minimum temperature at Groningen Airport (at a distance of 7 km from the

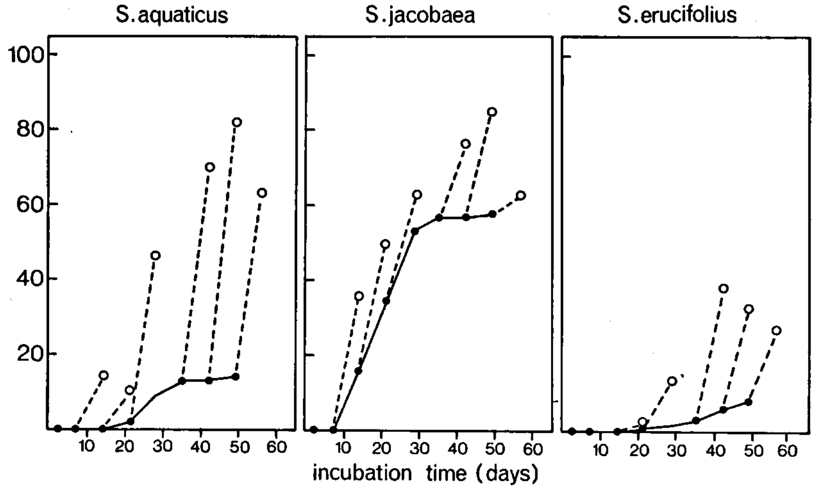

Fig. 2. Germination rate of achenes of three *Senecio* species at 5°C, as influenced by a single heat shock of 6 hours at 25°C at different times of incubation. ——— germination without heat shock; ○ germination within 1 week after the heat shock (● = heat shock).
100 = total number of viable seeds, as determined in a separate test at optimum incubation temperature.

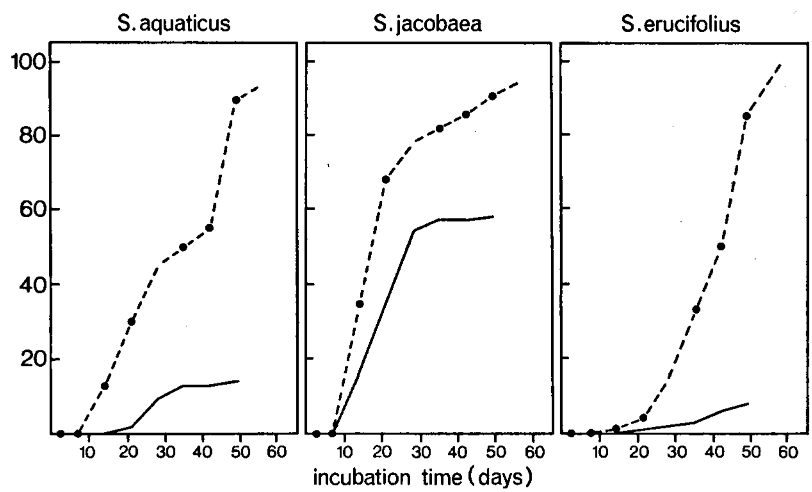

Fig. 3. Germination of achenes of three *Senecio* species at 5°C, as influenced by repeated heat shocks of 6 hours at 25°C. ——— germination without heat shocks; ------ germination with repeated heat shocks (● = heat shock).
100 = total number of viable seeds, as determined in a separate test at optimum incubation temperature.

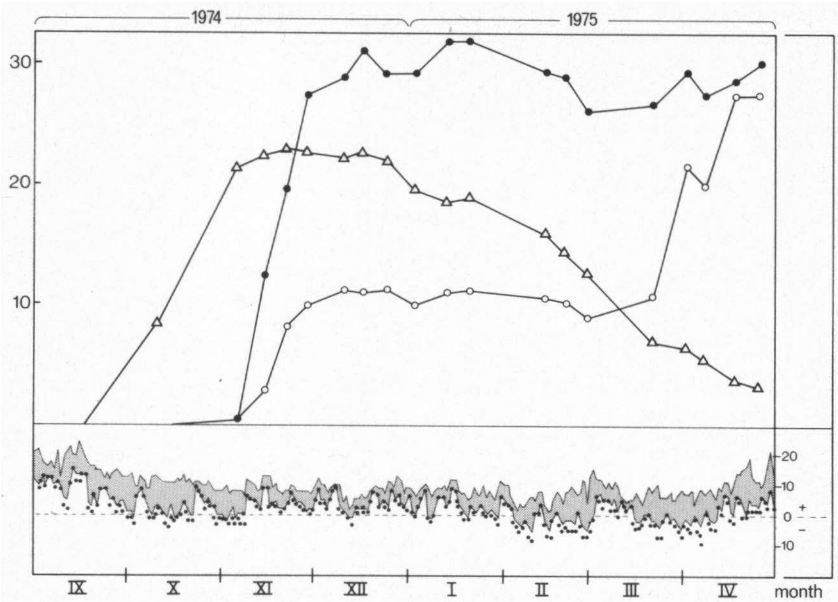

Fig. 4. Number of emerging seedlings in percentages of achenes sown on plastic buckets in the experimental garden: ○ *S. aquaticus*; ● *S. jacobaea*; △ *S. erucifolius*.
Below: daily averages of maximum and minimum air temperatures in °C at 1.5 m above earth's surface as measured at Groningen Airport Eelde; (•) minimum temperatures at 10 cm above earths surface.

experimental garden) are summarized in *fig. 4*. Between subsequent counts achenes may have germinated and seedlings may have died, but these two processes are not determined separately. However, some conclusions seem secure.

The number of seedlings of *S. aquaticus* remains much lower during the cold season than that of *S. jacobaea*, which agrees with the germination experiments. *S. erucifolius* cannot be compared to these two species, for its achenes were sown a month earlier and thus underwent higher temperatures. The strong decrease in the number of seedlings of *S. erucifolius* during winter is striking; in spite of the very mild winter of 1974–1975, much frost damage to the seedlings was observed.

Next April no new seedlings were observed. Thus only a small number of germinable seeds seems to be left.

B. Roadside. In the rows sown at October 9 and 25, 1975, no seedlings were found. In the rows sown at March 8 and April 7, 1976 a small number of seedlings established; some of them flowered in the same year. Some of these plants were still present in midsummer 1980. Apart from these plants, virtually no individuals of *S. erucifolius* were observed in the verges of this new road. Arrival of seeds on these verges from the existing population lying nearby and in the prevailing wind direction, is very probable.

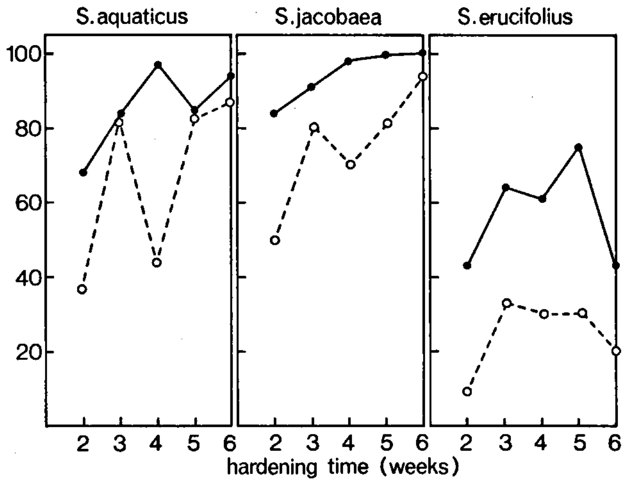

Fig. 5. Survival % of seedlings, growing under frost-hardening conditions, 24 days after exposure to −5 °C during 48 h (———) and 72 h (-----).

3.3. Frost tolerance of the seedlings

The survival of seedlings, exposed 24 days earlier to −5 °C during 48 and 72 hours as related to the period of growing under frost hardening conditions, is shown in *fig. 5*. A recovery time of 24 days was chosen because after this time no mortality occurred. Although the results are irregular, the seedlings of *S. erucifolius* appear to be more frost-sensitive, than those of the other two species and also in

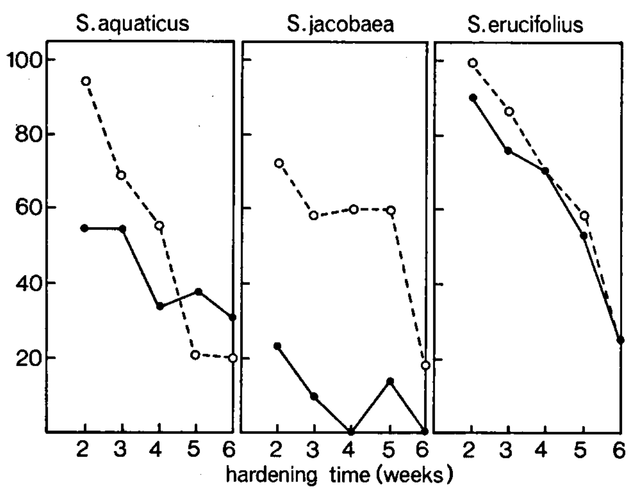

Fig. 6. Reduction of dry matter production (%) of the surviving seedlings of *fig. 5*, after 10 weeks under frost-hardening conditions, as compared to plants without a frost treatment. ——— 48 h at −5 °C. ----- 72 h at −5 °C.

contrast, their frost-tolerance during the stay of 6 weeks under hardening conditions has not increased.

After the frost treatment the growth of the surviving seedlings of *S. erucifolius* was more impeded than in the other species (*fig. 6*). The decrease in growth was stronger when the frost-treatment took place earlier in the fixed growing period. In contrast to the other species in *S. erucifolius* the duration of the frost-treatment was of little influence on the development of the surviving seedlings. Here we conclude that the frost-treatment and its duration leads to a selection in experimental seedling populations of the three species. One may expect that the genetic variability within this isolated population, perhaps belonging to one clone, must be smaller than in the populations of the other two species.

4. DISCUSSION

The results indicate that *S. erucifolius* is badly equipped for generative reproduction in a northern atlantic climate. *S. erucifolius* flowers much later and the achenes are not dispersed until September.

The time of flowering is determined by temperature rather than by daylength, as may be judged from the following observations: rosettes of the three species, when transplanted from the experimental garden to the heated greenhouse in February, flowered simultaneously after 2 months; in the warm summer of 1976 the Friesland field population of *S. erucifolius* flowered about 2 weeks earlier than in previous years.

The optimum germination temperature of freshly harvested seeds of *S. erucifolius* is high, at least when compared to *S. jacobaea*. *S. aquaticus* resembles *S. erucifolius* with respect to the germination response to temperature, but it flowers much earlier, *viz.* June.

The scanty data on the reproduction and ecology of species growing at their northern range agree with the results presented here. BANNISTER (1978) transplanted heath plants from different latitudes to the same latitude. He found that the time of flowering of the transplanted individuals was positively correlated with their original latitude. TYLER et al. (1978) found that seeds of a tetraploid variety of *Festuca pratensis* from higher alpine altitudes, need a cold treatment for germination and the emerging seedlings were frost-tolerant; the diploid species from lower altitudes did not show these characters.

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