

Chapter (non-refereed)

Park, D. G.. 1982 Seedling demography in quarry habitats. In: Davis, B. N. K., (ed.) *Ecology of quarries: the importance of natural vegetation*. Cambridge, NERC/ITE, 32-40. (ITE Symposium, 11).

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SEEDLING DEMOGRAPHY IN QUARRY HABITATS

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INTRODUCTION

Seed and seedling ecology have been largely overlooked in the study of quarries, but are areas of importance when considering the natural colonisation of these habitats. Quarrying initiates a primary succession with the removal of existing vegetation, the mineralised soil layer and the seed bank. Colonisation by plants of these denuded areas will be dependent on the influx of seed/propagules from external sources and the actual rate of colonisation will be dependent upon the outcome of seedling establishment and subsequent seedling survival.

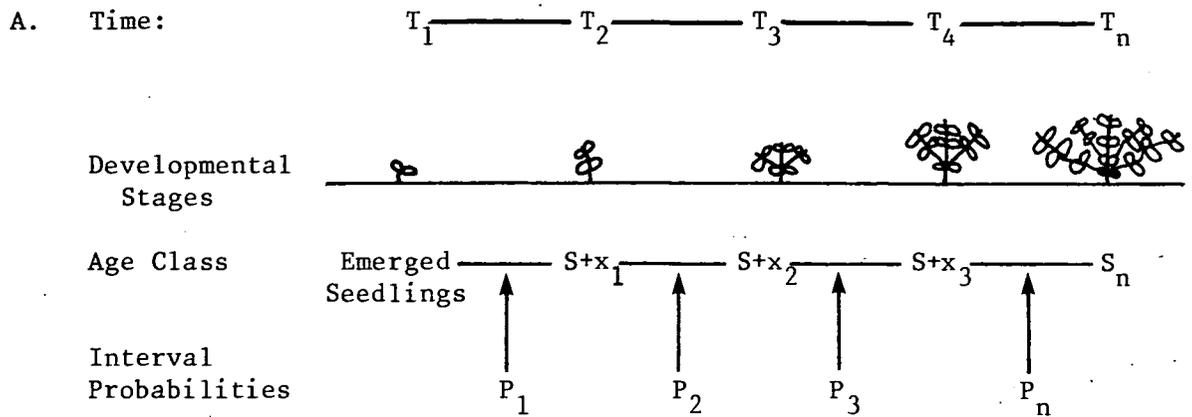
A study has been made of both natural and experimental seedling populations of several common plant colonists. Particular attention has been given to rates of recruitment and mortality, and to ways in which these rates may be modified by experimental treatments. Results from this work will be reported in the paper.

GENERAL ASPECTS OF SEEDLING ECOLOGY

Although the natural colonisation of disused quarries has produced a rich diverse flora, a long developmental period is often required before an appreciable cover of vegetation is established. The community remains open with much bare ground. In such a situation, the opportunity for recruitment to seedling population is likely to be greater than that in a closed community where recruitment depends on the occurrence of gaps in the vegetation cover. However, seedling mortality must be severe otherwise this open community structure would not be a persistent feature of the quarry floor habitat.

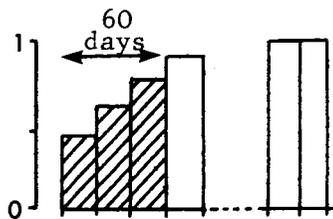
Rates of mortality among juvenile plants are very high: the young seedling is the most susceptible phase in the ontogeny of the individual and mortality generally decreases with age. This can be demonstrated in the following simple way.

1. If an individual's ontogeny is divided into a number of discrete intervals by separating either developmental stages or age states (Figure 4A), it is possible to assign probability values (P_i) to the chances of passing from one stage/state to the next.
2. Multiplication of the interval probabilities (P_i) gives the overall probability that an individual reaches a certain stage of development or age (Figure 4B).
3. Probability histograms for the P_i 's for a generalised perennial and an annual show two alternatives (Figure 4C). In the first, a postulated increase in interval probability values with age/development gradually levels off. In the second, the postulated increase continues until a point is reached, perhaps coincident with flowering, when probability values decline sharply.
4. Consider the shaded areas of the histograms covering seedling establishment up to a limit of 60 days; the calculated probability of an individual passing from emerged seedling to a sixty-day old seedling is of the order 0.18-0.75, depending on species, for seedlings on quarry floors (Figure 4D). Similar work in America gives a slightly lower range of 0.08-0.55 (Skaller 1977).

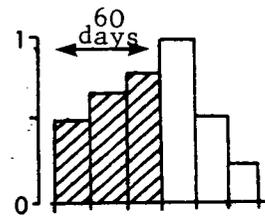


B. $\text{pr}(\text{Emerged Seedling} \longrightarrow S+x_3) = P_1 \times P_2 \times P_3$

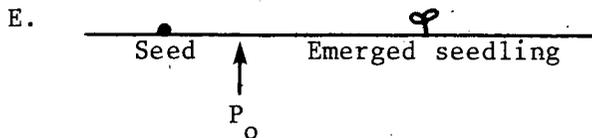
C. Probability Histograms - perennial



annual



D. Quarry floor species: $\text{pr}(\text{Seedling} \longrightarrow S+60 \text{ days}) = 0.18-0.75$



Quarry floor species: $\text{pr}(\text{seed} \longrightarrow \text{seedling} + 60 \text{ days}) = 0.02-0.10$

Figure 4 Survival probabilities in seedlings

5. However, if the interval from seed to emerged seedling is also included, then the probability that an individual passes from seed to sixty-day old seedling falls abruptly to 0.02-0.10 (Figure 4E).

From this it would appear that the major limiting period of natural colonisation is the passage from seed to seedling. For the particular quarry studied by Skaller, it was concluded that seed input was not a limiting factor in the colonisation process but rather the events following the arrival of seeds on the spoil surface.

COHORT VARIABILITY

The approach outlined above, while showing the magnitude of seed/seedling loss, is an over-simplification and does not show one important aspect of seedling ecology - that of cohort variability. Baskins & Baskins (1972) found that early germinating cohorts of *Leavenworthia stylosa* suffered high mortality but had a greater probability of flowering, whereas later germinating cohorts avoided such severe early mortality but had a lower probability of flowering. This general relationship can be found in quarry seedling populations but an overall influence is exerted by the prevailing climatic conditions. Seedling emergence and mortality from a permanent quadrat established on a quarry floor, was studied intensively for two years and seedling survivorship curves were constructed for different cohorts (Figure 5). During 1979, germination was curtailed by the dry conditions occurring during June/July and the relationship between early and late cohorts is not shown. However, during 1980 this relationship can be clearly seen.

One of the most noticeable aspects of seedlings emerging in quarry habitats is the long period of time they spend at a small size and at an early stage of development (at the cotyledon, first and second leaf stages). Research elsewhere has shown that annual growth rates are small and it is common to find annuals and perennials remaining as basal rosettes for extended periods of time (Raynal 1979, Klemow & Raynal 1981). Perhaps the single most important characteristic of juvenile plants that influences their fitness is their size during environmental stress. Mortality is strongly dependent on size with smaller individuals suffering greater hazards. For many plants the total length of the juvenile period will be a function of size - itself a function of growth rates which reflect, amongst other things, nutrient availability.

CAUSES OF SEED AND SEEDLING LOSSES

1. The most important causes of seed losses during the early stages of colonisation are probably physiographic processes such as wind and water erosion and frost heave, leading to seed burial. In an experiment on the recovery of dyed seeds sown on to a bare quarry floor, losses amounted to 20-50% after 25 days, 30-75% after 50 days and 60-90% after 125 days (which included an overwintering period). Seeds were found to have moved down the spoil profile during the course of the experiment.
2. Probably the most important factor causing seedling mortality is desiccation acting both directly, during periods of drought, and indirectly, for example after spoil movement and exposure of roots. The spoil is freely drained and the surface dries relatively quickly: during late spring and summer the moisture content of the spoil is frequently below the permanent wilting point (Figure 5).
3. Failure of the radicle to penetrate the spoil, as a result of the formation of a cementation layer or because of waterlogging of the spoil.
4. Predation or grazing by invertebrates can cause high mortality in seedling populations and may be selective in nature.
5. High surface temperatures may cause death directly and are certainly capable of stress through effects on evapotranspiration.
6. In active quarries, the adverse effects of dust can be important: dust on leaves reduces photosynthesis, interferes with transpiration and increases the risk of disease. The overriding influence of nutrient deficiency may increase the effect of these mortality agents, for example plants become more susceptible to water stress.

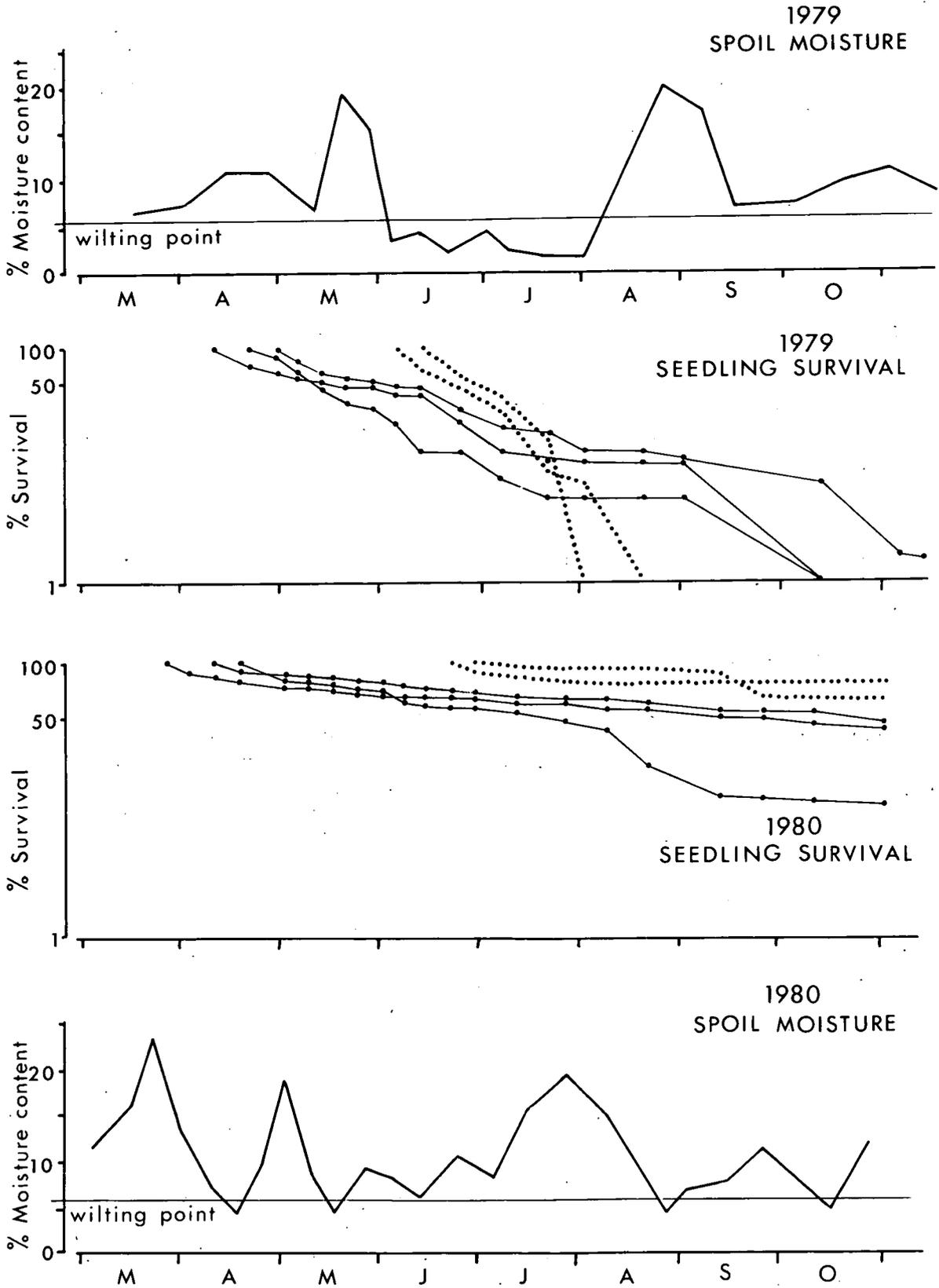


Figure 5 Spoil moisture and seedling survivorship curves for 1979 and 1980; data from a permanent quadrat study. Survivorship curves are for total seedlings emerging

EXPERIMENTS ON *ORIGANUM VULGARE*

Some of these points may be illustrated by reference to a particular species, studied in a quarry habitat. *Origanum vulgare* (marjoram) is a common constituent of quarry floras: it is an aromatic perennial herb with a bushy appearance. The seeds are small (6.4×10^{-5} g) and produce seedlings of only a few millimetres in size. During February 1980, a number of areas of quarry floor were artificially seeded, and seedling emergence, survival and development were monitored intensively throughout the year. The quarry floor consisted of a shallow layer (0-10cm) of crushed limestone or spoil overlying the baserock: the spoil contained little or no organic material, was freely drained and poor in both macro- and micro-nutrients.

Germination in the plots began in April and was more or less complete by July; total plot germination was in the range 18-51% and compared with a laboratory germination value of over 90%. The population flux of one of the seeded areas is illustrated (Figure 6A) and shows cumulative germination, cumulative mortality and the number of seedlings present. The seedling population peaks in early May and then declines to a level which remains relatively stable throughout July-October. Cohort survivorship curves (Figure 6B) clearly demonstrate the relationship between early and late cohorts remarked upon earlier. However, during the following winter, the population was greatly reduced by the effects of frost heave, with only 1-3% of the seedlings surviving to March 1981.

During the monitoring of the plots, the seedlings present were classified according to six stages of development (Figure 7). The histograms in this figure give the proportional representation of these classes at the dates indicated. Histogram 8 (November) shows that even after a considerable period of time (around 180 days) most of the seedlings are still at an early stage of development. Age-class frequency distributions of the seedlings are also shown for selected dates (Figure 8). The developmental stages do not reflect age classes. The size of an individual, which often reflects its stage of development, is more important in determining its behaviour than its chronological age (Gross 1981, Werner 1975).

O. vulgare was also used in experiments designed to increase recruitment and reduce mortality. A sawdust mulch was applied to sown plots of *O. vulgare*. Recruitment in plots mulched with sawdust was very much higher than in non-mulched plots and much of the early seedling mortality was avoided (Figure 9). The main effect of the mulch was to increase the spoil moisture 2-4%. Although recruitment and seedling survival were found to be greater in mulched plots, the rate of seedling development was unaffected and was similar to that of non-mulched plots.

CONCLUSIONS

Seedling ecology forms an important part of the study of a primary succession such as that occurring in disused quarries. The seedling represents one of the most susceptible and vulnerable stages during the ontogeny of a plant; rates of recruitment and mortality in seedling populations may influence the rate at which colonisation proceeds.

ACKNOWLEDGEMENTS

This work was funded by a Natural Environment Research Council Institute award. Dr B N K Davis and Mr R N Humphries gave valuable help in the planning of the research programme and in the preparation of the manuscript.

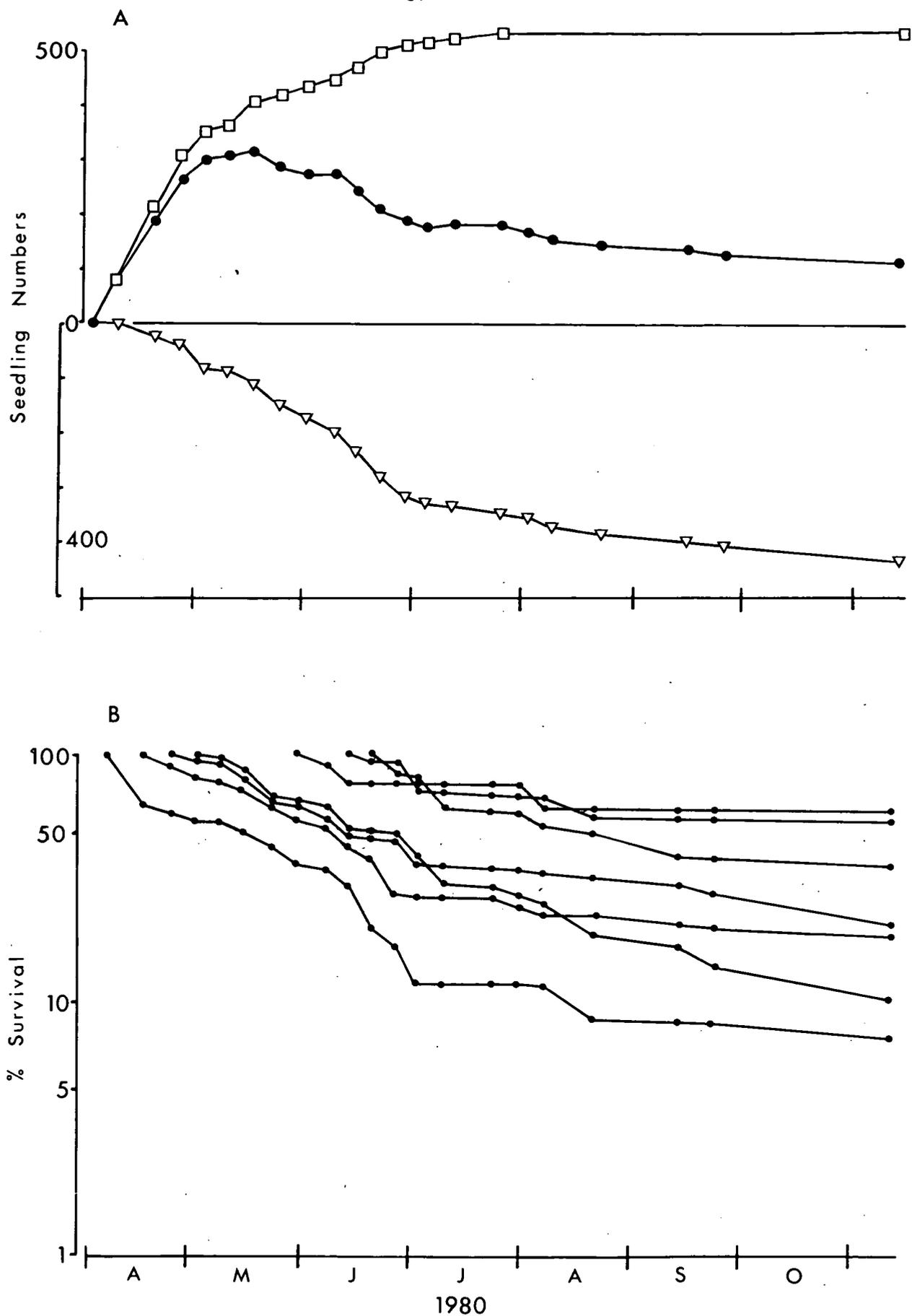


Figure 6 *Origanum vulgare*: seedling emergence and mortality. A: population flux diagram \square - \square cumulative recruitment, ∇ - ∇ cumulative mortality, \bullet - \bullet seedlings present. B: cohort survivorship curve.

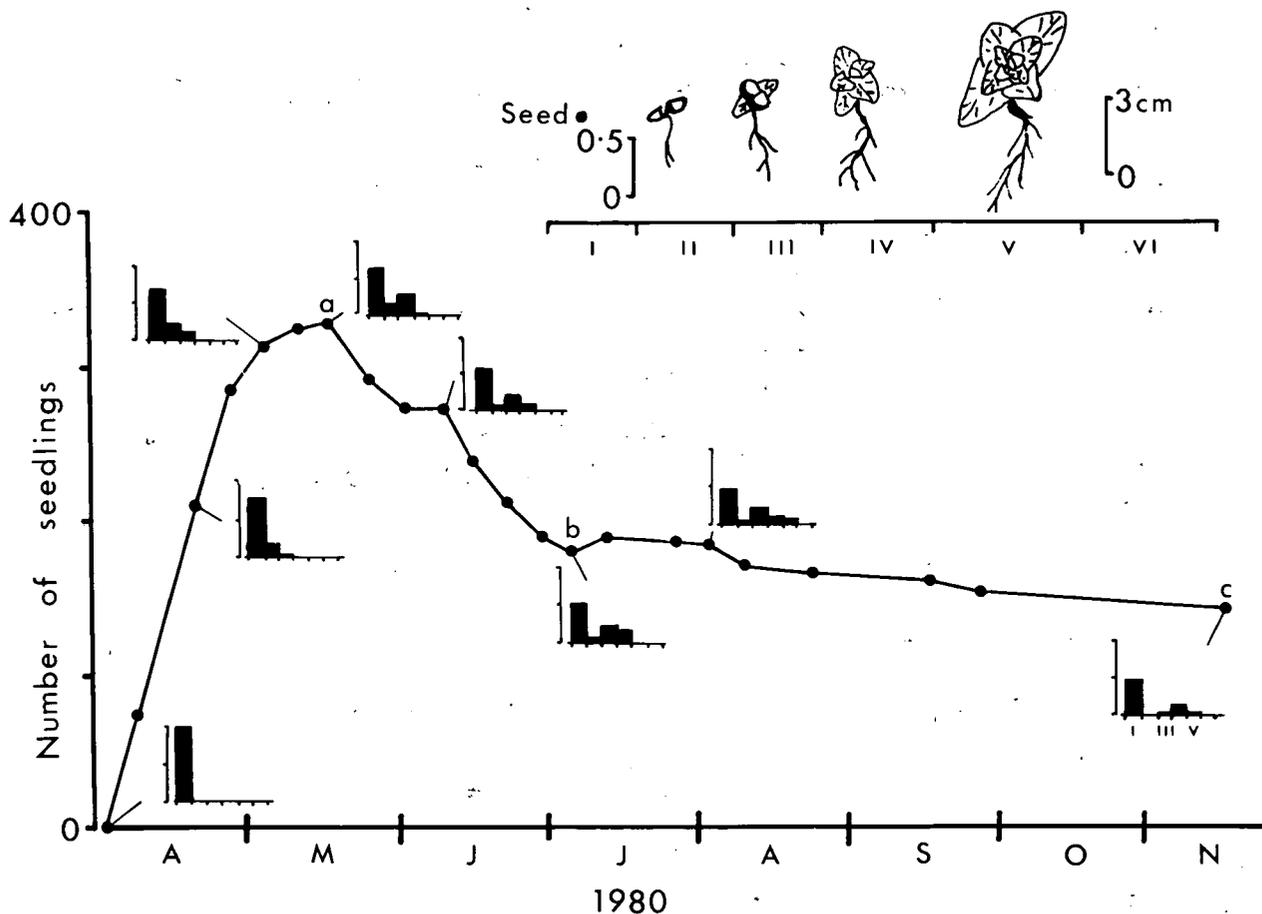


Figure 7 *Origanum vulgare*: Developmental stage analysis (as a proportion of seeds sown) at selected dates.

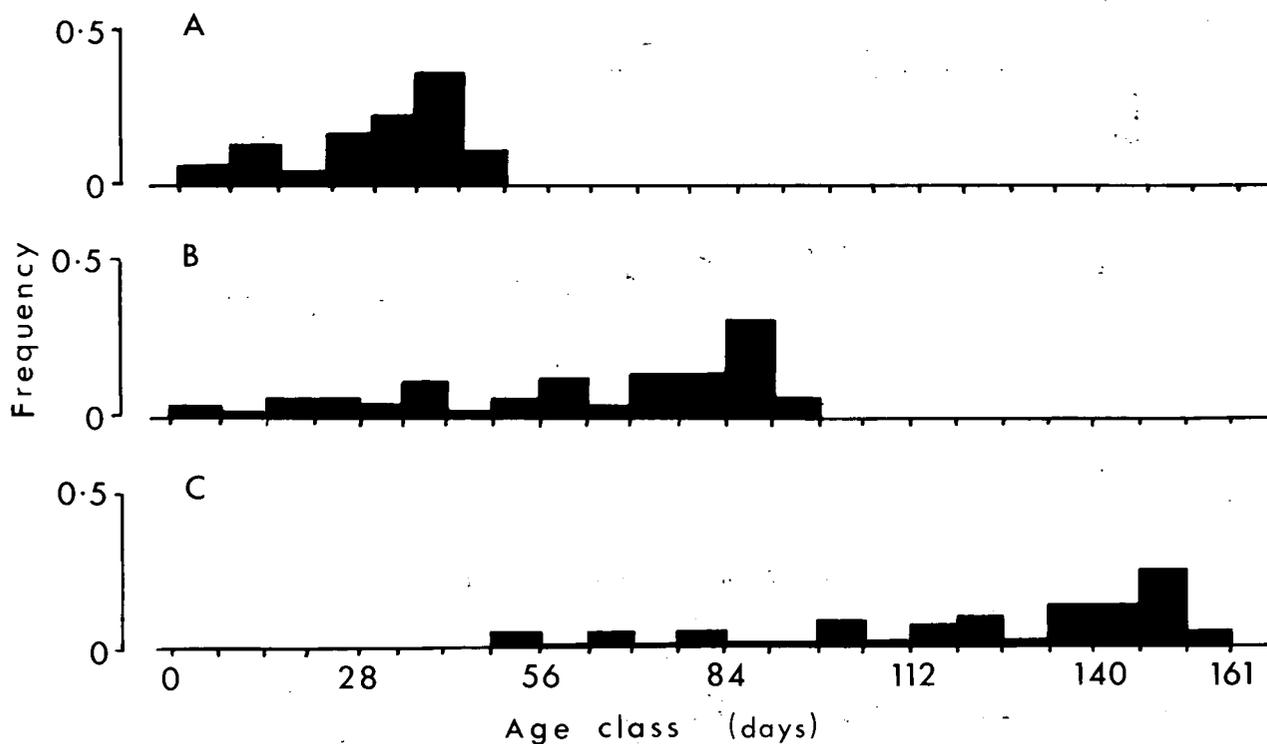


Figure 8 *Origanum vulgare*: Seedling age-class distribution (as a proportion of seedlings present) at three dates.

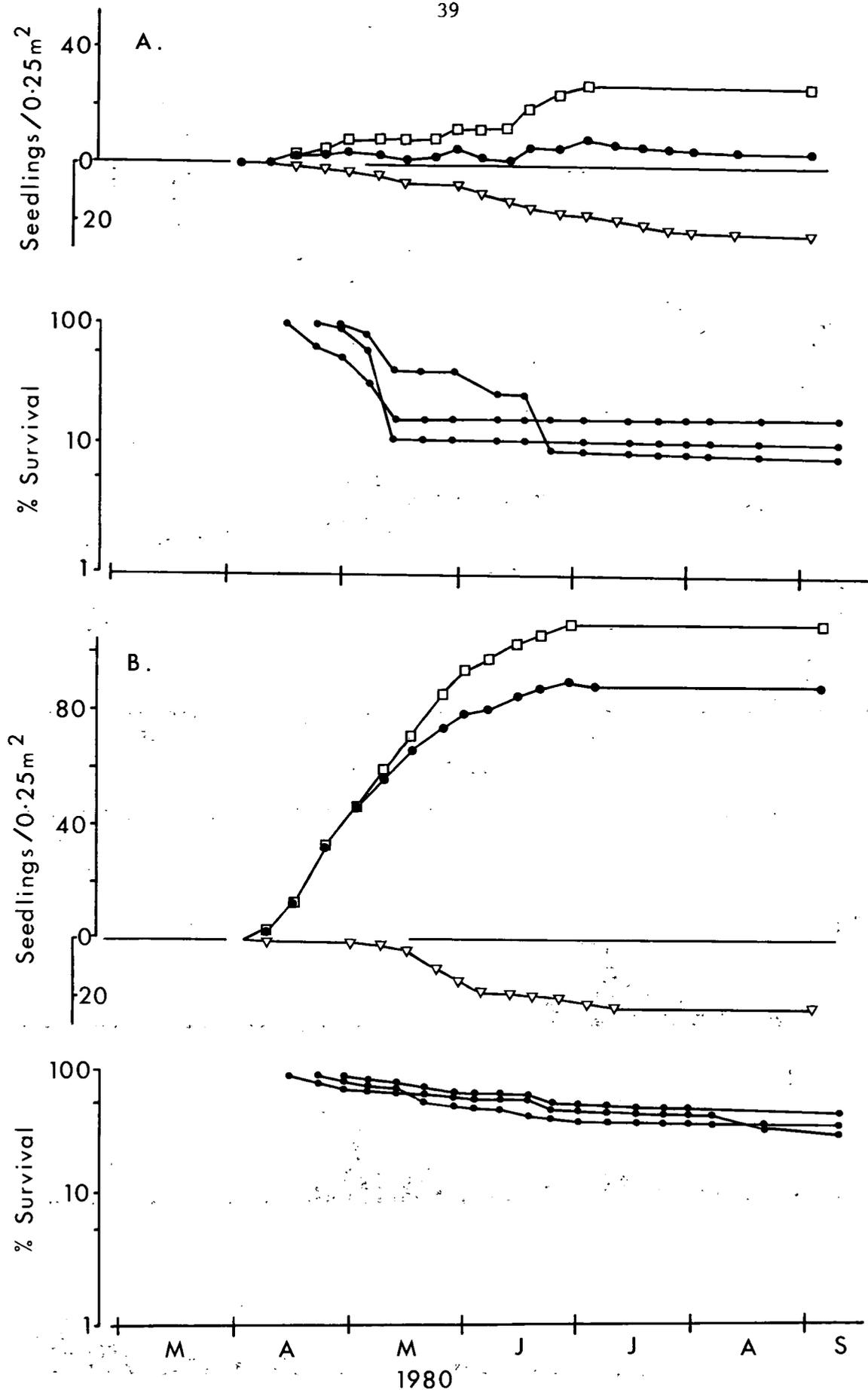


Figure 9 *Origanum vulgare*: Population flux diagrams and cohort survivorship curves (mean results from three replicates)
 A: non-mulched plots B: mulched plots

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