

Variation in Germination and Seedling Growth of *Taraxacum officinale* Seeds Harvested from Different Seasons

Yang, Hyo-Sik

Department of Biology, College of Science, Mokpo University

ABSTRACT: Differential response of genotypes to temporal environmental heterogeneity may contribute to the long-term persistence of these genotypes within a population. In this experiment, we experimentally tested whether groups by season interactions for germination and seedling growth can explain genetic variability within the population. To determine whether seeds collected during the four seasons respond differentially to temperature treatments, two-way ANOVA was performed. This study indicates that seasonal environments have large effects on demography. Groups within populations respond differentially to seasonal environments by influencing population growth that may in turn influence community composition. Most importantly, the study showed that temporal heterogeneity in the environment might function as a mechanism that maintains within-population genetic diversity.

Key words : Cool- and warm season, Fitness, Seasonality, Temporal variation.

INTRODUCTION

Plant populations exist in a heterogeneous environment. In temperate zone, many abiotic factors that fluctuate seasonally are temperature, precipitation, and photoperiod (Vavrek *et al.* 1996, 1997). Population growth and decline have been found to vary as a function of this heterogeneity (e.g., Selman 1970, Sharitz and McCormik 1973, Sarukhan and Gadgil 1974). To understand the consequences of environmental heterogeneity on population growth, vital demographic rates have been observed across time and space. For example, differences in annual demographic rates have been shown for *Arisaema triphyllum* (Bierzuchudek 1982), *Bromus tectorum* (Mack and Pyke 1984), *Alnus incana* (Huenneke and Marks 1987), *Ascophyllum nodosum* (Aberg 1992), and *Collinsia verna* (Kalisz and McPeck 1992). Differences in rates across space also are commonly found (e.g., Werner and Caswell 1977, Schweagerle and Bazzaz 1987, Kalisz 1991). Moloney (1988) explicitly examined demographic rates of *Danthonia sericea* across temporal and environmental gradients and concluded that rates are sensitive to fine-scale environmental heterogeneity. This environmental control of plant demography has implications for population stability and distribution. For example, population size and dispersion may fluctuate as a result of differential sensitivity of population growth to environmental change across space and time. Differential demographic rates within populations may also serve as indicators of underlying genetic composition, life histories, and evolutionary change.

Temporal environmental heterogeneity occurs both among

years and within years (seasonally). Several studies have incorporated seasonal variation in their studies (e.g., Sarukhan and Gadgil 1974, Law 1981), but have not specifically examined differential demographic responses of plant populations across seasons (with the exception of Bullock, Clear Hill and Silvertown 1994). Variation in demography among seasons, however, may be greater than variation among years because seasonal variation in weather is generally large relative to annual differences. In south- and north-temperate climates, temperature and precipitation are clearly season-dependent. Analysis of temperature variation in a typical site of southwestern Korea (KMA 1991-2000, Mokpo, Korea), for example, yields little effect of year ($F=0.04$, $p=1.000$), but a large effect of season ($F=784.87$, $p<0.001$).

Seasonal variation in temperature, precipitation, irradiance, and photoperiod directly affect plant populations (Vavrek *et al.* 1996). Indirect effects also occur because seasonal weather patterns influence rates of mineralization (Williams 1969, Davy and Taylor 1974, Morecroft, Marrs and Woodward 1992), evapotranspiration (Caprio 1974), and decomposition (Katz and Lieth 1974, Rochow 1974). Changes in these rates, in turn, influence resource abundance and availability to plants.

Seasonal weather patterns also influence a plant population's biotic environment. The diversity and dominance of pathogens (Purdy 1966, Jacome and Schuh 1992, Morin, Brown and Auld 1992), herbivores (Reader 1985) and interspecific competitors (Grubb 1977, Al-Mufti *et al.* 1977, Turkington and Harper 1979, Fowler and Antonovics 1981) vary as a function of season. Seasonal differences in the biotic environment of a population may be as great an influence on plant performance and resource avail-

* Author for correspondence; Phone: 82-61-450-2340, Fax: 82-61-454-0267, e-mail: hsyang@intra.mokpo.ac.kr

ability as the direct effects of fluctuations in natural environments.

Vital demographic rates of plant populations respond to these large environmental differences among seasons and thus are highly dynamic through time. Information about demographic rates across seasons may serve to clarify population responses to invasion, perturbation, and other environmental changes. Population response may occur only in particular seasons, and may therefore be obscured with census taken annually.

Population-level demographic rates may also be influenced by genotype-specific responses to seasonal environmental change. Differential genotypic responses may underlay overall demographic patterns and may serve to maintain genetic variability within the population, just as genotype-environment interactions can maintain genetic variation (Antonovics 1976).

In this experiment, we experimentally test whether group by season interactions for germination and seedling growth can explain genetic variability within the population.

METHODS

Taraxacum officinale is a ubiquitous, herbaceous perennial commonly found in lawns, meadow, and disturbed areas. *T. officinale* generally maintains foliage throughout the entire year in Korea.

Seeds of a natural population of *T. officinale* within the Mokpo University lawn, were collected in same plant throughout the entire year of 1999 for this study. All seeds were stored in paper bags at 4°C. These seeds were classified four seasonal groups. These seasons, spring (April to July; A), summer (July to October; B), autumn (October to January; C), winter (January to April; D), were selected based upon monthly climatic patterns and demographic patterns of natural population of *T. officinale* (Vavrek 1994).

Random samples of seeds from each of the four groups were germinated in 10cm diameter petri dishes with a double layer filter-paper. Dishes were placed in incubators set at four temperatures (15°C, 20°C, 25°C, 30°C) based upon whether of natural population of *T. officinale*. Three replicates of each combination were randomly placed in each of four incubators. All petri dishes were watered and were counted once daily during two weeks.

Some days after seeds were planted for germination, seedlings germinated were transferred into the petri dishes of a

growth chamber (25°C; 74 μmol m⁻²s⁻¹; 24h photoperiod) during one week to observe growth of young seedlings. Seedling dry weight was measured after drying for a week at about 80°C in an oven.

To determine whether seeds collected in the four seasons respond differentially to temperature treatments, two-way ANOVA was performed. All analyses were performed using SAS JMP (v 3.0) (1991).

RESULTS AND DISCUSSION

The pattern of temperature change during the seed collection was typical for a temperate climate (Fig. 1). Analysis of temperature variance for the survey site in southwestern of Korea peninsula (KMA 1991-2000, Mokpo, Korea) yielded little effect of year ($F=0.04$, $p=1.000$), but a large effect of season ($F=784.87$, $p<0.001$) repetitively.

The germination velocities appear to appear to be distinct (Tables 1 and 2). The germination velocities of seeds in spring and autumn groups were greater than the summer and winter groups (Table 1), especially at 20°C environment.

The germination rates of four seasonal groups appear to be distinct (Table 2 and Fig. 2). The germination rates of seeds in spring and autumn groups were greater than the summer and

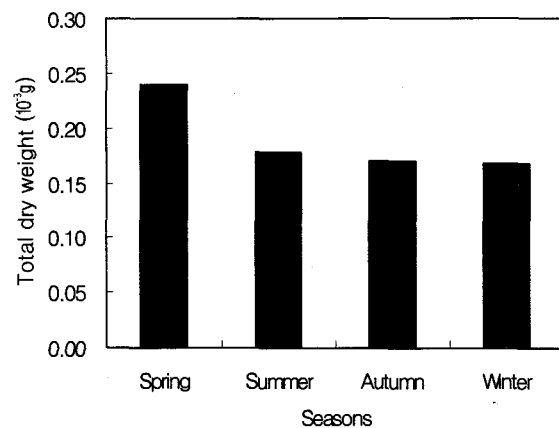


Fig. 1. Mean temperature of Mokpo, Chonnam, Korea from 1991 through 2000.

Table 1. Index of germination velocity of biotypes of *Taraxacum officinale* population

Temperature(°C)	Biotypes			
	Spring	Summer	Autumn	Winter
15	12.73 ± 1.23	2.07 ± 0.20	17.47 ± 3.18	2.40 ± 0.60
20	18.23 ± 1.90	2.67 ± 0.76	25.30 ± 2.10	2.33 ± 0.14
25	15.90 ± 1.57	3.93 ± 1.53	20.90 ± 1.81	8.80 ± 0.62
30	11.56 ± 0.85	0.53 ± 0.46	8.45 ± 0.96	0.87 ± 0.12

Table 2. F-values from ANOVAs showing the effect of population and temperature treatment regime on germination rate and velocity of *Taraxacum officinale*

Source of variation	df	Germination rate	Germination velocity
Population	3	474.88 ***	49.05***
Temperature treatment	3	72.13 ***	288.20***
Population × Temperature treatment	9	8.14**	13.08***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

winter groups (Table 1, Fig. 2), especially at 20 °C environment. These differences in germination response to temperatures resulted in genetic correlations to explain adaptation types of natural habitats.

The total dry weight of the four groups (Fig. 3) appear to be not distinct ($p = 1.29$, $F = 0.284$). But Total dry weight of spring group is a little higher than others, and this difference don't have statistically significant.

The environmental gradient from January to December is a complex one in which light, herbivory, disturbance, water potential and possibly nutrients vary as well as temperature. The pre-

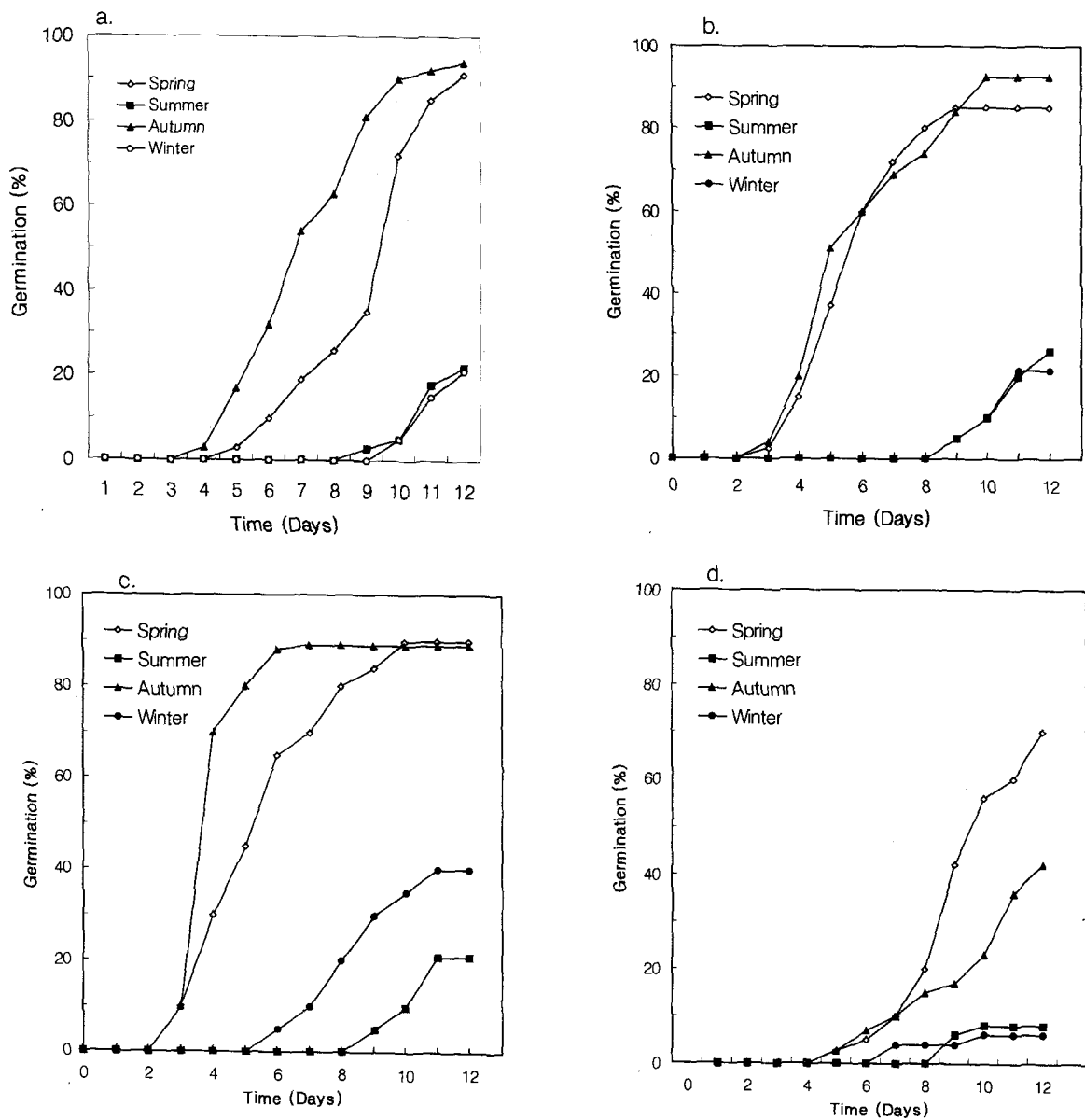


Fig. 2. Differential response in germination of *Taraxacum officinale* seeds collected at four seasons to temperature treatments (a: 15 °C, b: 20 °C, c: 25 °C, d: 30 °C). Seeds originated from a population in Mokpo University campus, Chonnam, Korea.

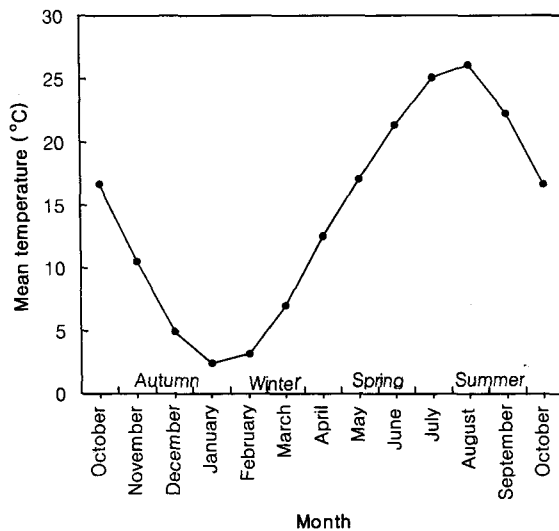


Fig. 3. Total dry weight of *Taraxacum officinale* groups cultured in 25°C growth chamber for a week.

sent study, by examining response to temperature alone, demonstrates genetic difference in the ability of the four groups to temperature in manner consistent with that observed along the multifactorial gradient in field. The germination velocities and rates of autumn groups is higher than other groups when given 20~25°C environments. This pattern, in which a population adapted to relatively high resource levels is more plastic in response to gradients, has been observed in many other studies of ecotypic variation (Gurevitch *et al.* 1986, McGraw 1987, Fetcher and Shaver 1990).

The differential temporal responses by groups is illustrated by the classification of spring, summer, autumn and winter groups. This differential response means that these groups are not directly competing for resources during times of rapid growth and recruitment or that competitive ability changes as a function of season. Temporal environmental variation has been suggested as a causal factor in the maintenance of species diversity within communities (Fowler and Antonovics 1981, Chapin and Shaver 1985).

This study indicates that seasonal environments have large effects on demography. Groups within populations respond differentially to seasonal environments influencing population growth that may in turn influence community composition. Most importantly, the study has shown that temporal heterogeneity in the environment may be a mechanism that maintains within-population genetic diversity.

LITERATURE CITED

- Aberg, P. 1992. A demographic study of two populations of sea-weed *Ascophyllum nodosum*. *Ecology*, 73: 1473-1487.
- Al-Mufti, M. M., C. L. Sydes, S. B. Furness, J. P. Grime and S. R. Band. 1977. A quantitative analysis of shoot phenology and dominance in herbaceous vegetation. *J. Ecol.* 65: 759-791.
- Antonovics, J. 1976. The input from population genetics: "The new ecological genetics". *Systematics Botany* 1: 233-245.
- Bierzychudek, P. 1982. The demography of Jack-in-the-pulpit, a forest perennial that changes sex. *Ecol. Monog.* 52: 335-351.
- Bullock, J. M., B. Clear Hill and J. Silvertown. 1994. Tiller dynamics of two grasses-responses to grazing density and weather. *J. Ecol.* 82: 331-340.
- Caprio, J. M. 1974. The solar thermal unit concept in problems related to plant development and potential evapotranspiration. *Phenology and Seasonality Modeling*. Springer-Verlag, New York. pp. 353-364.
- Chapin, F. S. III and G. R. Shaver. 1985. Individualistic growth response of tundra plant species to environmental manipulations in the field. *Ecology* 66: 564-574.
- Davy, A. J. and K. Taylor. 1974. Seasonal patterns of nitrogen availability in contrasting soils in the Chiltern Hills. *J. Ecol.* 62: 793-807.
- Fetcher, N and G. R. Shaver. 1990. Environmental sensitivity of ecotypes as a potential influence on primary productivity. *The American Naturalist* 136: 126-131.
- Fowler, N. and J. Antonovics. 1981. Competition and coexistence in a North Carolina grassland. I. Patterns in undisturbed vegetation. *J. Ecol.* 69: 825-841.
- Grubb, P. J. 1977. The maintenance of species-richness in plant communities: the importance of the regeneration niche. *Biological Review* 52: 107-145.
- Gurevitch, J., J. A. Teeri and A. M. Wood. 1986. Differentiation among populations of *Sedum wrightii* (Crassulaceae) in response to limited water availability: water relations, CO₂ assimilation, growth and survivorship. *Oecologia* 70: 198-204.
- Huenneke, L. F. and P. L. Marks. 1987. Stem dynamics of the shrub *Alnus incana* ssp. *rugosa*. *Transition matrix models*. *Ecology* 68: 1234-1242.
- Jacome, L. H. and W. Schuh. 1992. Effects of leaf wetness duration and temperature on development of Black Sigatoka disease on banana infected *Mycopharella fijiensis* var. *difformis*. *Phytopathology* 82: 515-520.
- Kalish, S. 1991. Experimental determination of seed bank age structure in winter annual. *Ecology*. 72: 575-585.
- Kalish, S. and M. A. McPeck. 1992. Demography of an age-structure annual: Resampled projection matrices, elasticity analyses, and seed bank effects. *Ecology*. 73: 1082-1093.
- Katz, B. A. and H. Lieth. 1974. Seasonality of decomposers. H. Lieth (ed.), *Phenology and Seasonality Modeling*. Springer-Verlag, New York. pp. 163-184.
- Law, R. 1981. The dynamics of a colonizing population of *Poa*

- annua*. Ecology. 62: 1267-1277.
- Mack, R. N. and D. A. Pyke. 1984. The demography of *Bromus tectorum*: The role of microclimate, grazing and disease. J. Ecol. 72: 731-748.
- McGraw, J. B. 1987. Experimental ecology of *Dryas octopetala* ecotypes. IV. Fitness response to reciprocal transplanting in ecotypes with differing plasticity. Oecologia 73: 465-468.
- Moloney, K. A. 1988. Fine-scale spatial and temporal variation in the demography of a perennial bunchgrass. Ecology. 69: 1588-1598.
- Morecroft, M. D., R. H. Marrs and F. I. Woodward. 1992. Altitudinal and seasonal trends in soil nitrogen mineralization rate in the Scottish Highland. J. Ecol. 80: 49-56.
- Morin, L., J. F. Brown and B. A. Auld 1992. Effects of environmental factors on teliospore germination, basidiospore formation, and infection of *Xanthium occidentale* by *Puccinia xanthii*. Phytopathology 82: 1443-1447.
- Purdy, L. H. 1966. Soil moisture and soil temperature, their influence on infection by the wheat flag smut fungus and control of the disease by three seed-treatment fungicides. Phytopathology 56: 98-101.
- Reader, R. J. 1991. Relationship between seedling emergence and species frequency on a gradient of ground cover density in an abandoned pasture. Can. J. Bot. 69: 1397-1401.
- Rochow, J. J. 1974. Litter fall relations in a Missouri forest. Oikos 25: 80-85.
- Sarukhan, J. and M. Gadgil. 1974. Studies on plant demography : *Ranunculus repens* L., *R. bulbosus* L. and *R. acris* L. III. A mathematical model incorporating multiple modes of reproduction. J. Ecol. 62: 921-936.
- Schwaegerle, K. E. and F. A. Bazzaz. 1987. Differentiation among nine populations of *Phlox*: Response to environmental gradients. Ecology. 68: 54-64.
- Selman, M. 1970. The population dynamics of *Avena fatua* (wild oats) in continuous spring barley : Desirable frequency of spraying with Tri-allate. Proceedings of the 10th British Weed Control Conference 3: 1176-1188.
- Sharitz, R. and J. F. McCormick. 1973. Population dynamics of two competing annual plant species. Ecol. 54: 723-740.
- Statistical Analysis Systems Institute. 1991. JMP User's guide. SAS Institute, Inc. Cary, NC.
- Turkington, R. and J. L. Harper. 1979. The growth, distribution and neighbour relationships of *Trifolium repens* in a permanent pasture. IV. Fine-scale biotic differentiation. J. Ecol. 67: 245-254.
- Vavrek, M. C. 1994. Within-population variation in demography of *Taraxacum officinale*. PhD thesis, West virginia University, Morgantown, West Virginia, USA.
- Vavrek, M. C., J. B. McGraw and H. S. Yang. 1996. Within-population variation in demography of *Taraxacum officinale* : Maintenance of genetic diversity. Ecology. 77: 2098 - 2107.
- Vavrek, M. C., J. B. McGraw and H. S. Yang. 1997. Within-population variation in demography of *Taraxacum officinale* : season- and size-dependent survival, growth and reproduction. J. Ecol. 85: 277-287.
- Werner, P. A. and H. Caswell. 1977. Population growth rates and age vs. stage-distribution for teasel (*Dipsacus sylvestris* Huds.). Ecology. 58: 1103-1111.
- Williams, J. T. 1969. Mineral nitrogen in British grassland soils. I. Seasonal patterns in simple models. Oecologia Plantarum 4 : 307-320.
- (Received September 28, 2001, Accepted November 15, 2001)