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The Effect of Energy Allocation on Competition of *Chenopodium album* and *Digitaria sanguinalis*

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명아주(*Chenopodium album*)와 바랭이(*Digitaria sanguinalis*)의 競爭이 에너지 分配에 미치는 效果

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ABSTRACT

The effects of density and soil nutrient regime on competition between individuals in pure and mixed populations of two annuals, *Chenopodium album* and *Digitaria sanguinalis* were investigated at the level of enegy allocation. Seedling emergence of two species was extremely high (>90%) in both pure and mixed culture irrespective of the density and nutrient regime, but percentage of seedling establishment or fertile plant became gradually low with increasing density owing to 'self-thinning'. The mean plant dry weight was significantly reduced with increasing density and decreasing soil fertility. The dry matter production of *D. sanguinalis* in mixture was markedly greater than in pure culture under medium and high density.

Also, as considered the number of seed production as reproductive allocation, relationship between them and the number of seed production per plant showed a similar tendency. Therefore, these results indicated that *D. sanguinalis* had a greater competitive advantage than *C. album* and energy allocations to various organs were regulated by plastic response rather than determined genetically.

INTRODUCTION

Competition in plant communities is not always clear which aspects of the biology of a species allow it to coexist with other competing species, to become extinct, or to dominate and cause the exclusion of other species in a given area(Harper, 1967). Experimental studies of plant competition have usually focused on the effect of one biotic or abiotic factor on the growth of reproductive organ of one or several competing populations of plants. The factors which have been mainly studied included density(White and Harper, 1970; Kays and Harper, 1974), species compositions

(Marshall and Jain, 1969; Weiner, 1980), pattern(Mack and Harper, 1977), timing (Haizel and Harper, 1973), light(Kays and Harper, 1974) and concentration of specific nutrients(Pemadasa and Lovell, 1974c; Weiner, 1980).

The meanings of competing one plant species with the other may be connected with changes of an optimal allocation of resources or energy to life activities such as maintenance, growth and reproduction. Recently, the energy-allocation patterns have been the subject of much researches(Hickman, 1975, 1977; Abrahamson, 1979; King and Roughgarden, 1983). Abrahamson and Gadgil(1973) argued that if light is a limiting factor, then the growth form of the dominant competitor for light will be important in determining whether plants respond by either allocation more biomass to stem or leaves.

Therefore, the aim of this study was i) to examine the reaction of *C. album* and *D. sanguinalis* to different density and nutrient regime, and ii) to investigate the effect of energy allocation according to their competition.

MATERIALS AND METHOD

Seeds of *Chenopodium album* and *Digitaria sanguinalis* were collected from natural populations in Ewha Womans Univ. in autumn, 1984. Collected seeds were allowed to air dry and then stored in the dark at 5°C until using in experiment. In June 1985 the seeds were sown in plastic pots of 9cm diameter and 10cm depth filled with vermiculite and grown for twelve weeks in natural conditions.

Nutrient regime The plants grown under low nutrient received only water while those subjected to high nutrient regime received Hoagland nutrient solution twice a week. Usually the pots were watered twice a week.

Sowing pattern Two annuals were grown at three densities(6, 18, and 54 plants per pot) in pure and mixed culture of ratio 1 : 1. The three densities are subsequently referred to as low, medium and high, respectively. For low density, the plants were arranged in a hexagonal pattern and for medium and high density in a square pattern. All treatments were replicated three times.

Characters analysed Seedling counts were taken for all pots two weeks after sowing. At the end of the experiment, two plants were harvested, taking care to retrieve the root systems as compeletely as possible and dried at 70°C for several days until maintaining the constant weight. The weights of roots, stems, leaves, flowers and seeds were measured separately. The number of seeds was counted in case of *D. sanguinalis*. It was not practicable to estimate seed production per plant as *C. album* scattered its seed as soon as it is mature. However, since *D. sanguinalis* was two fertile floret per spikelet, the number of spikelet per plant can be used as a measure of relative fecundity.

RESULTS

Pure culture The data on seedling emergence in pure culture are summarized in Table 1. It is evident that more than 90% of the seeds of two species produced seedling. This indicated no significant effect of either density or soil nutrient regims on seedling emergence. Table 2 shows the data on seedling establishment. The probability of an emerged seedling surviving to maturity was reduced with increasing density. This trend of reduction appeared more strongly as growing to the fertile plants because of 'self-thinning' effects with increasing density. As shown in Fig. 1, the mean plant dry weight(above ground parts) was significantly reduced with increasing density($P<0.01$) but decreasing soil fertility($P<0.01$).

Mixed culture Seedling emergence in mixed culture with *C. album* and *D. sang. uinalis* was similar to that in pure culture described above, and so no detailed data

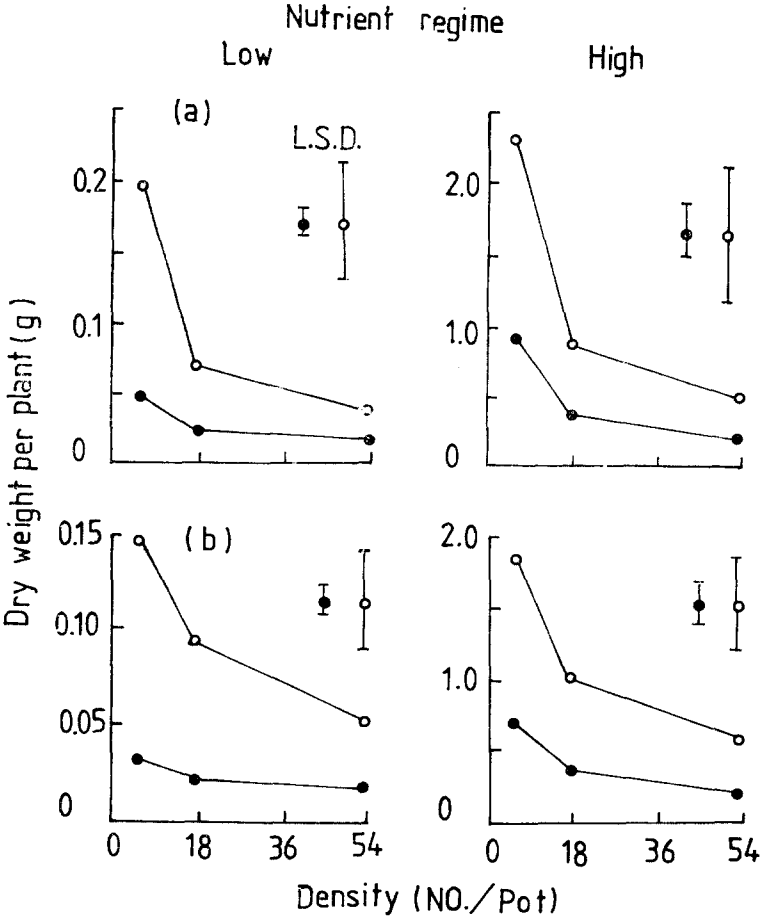

Fig. 1. Effect of density and nutrient regime on dry weight per plant in pure (a) and mixed (b) culture of *Chenopodium album* (●) and *Digitaria sanguinalis* (○).

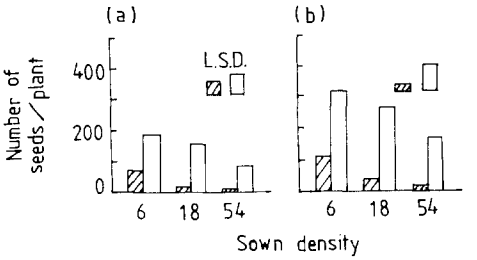

Fig. 2. Relationship between density and the number of seed production per plant in pure(a) and mixed (b) culture of *Digitaria sanguinalis* under different nutrient regimes. Open columns represent the high nutrient regime and the stippled columns the low nutrient regime.

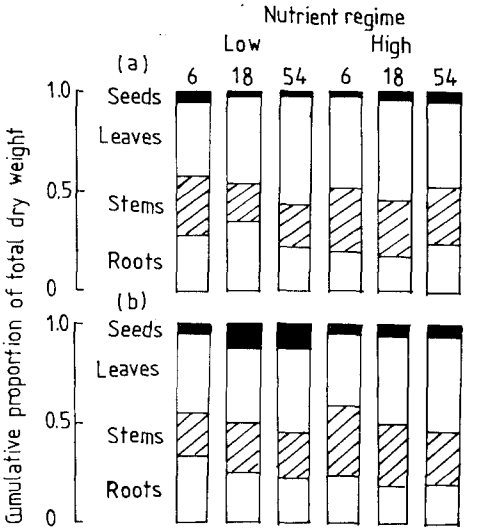

Fig. 3. Biomass allocation in pure (a) and mixed (b) culture of *Digitaria sanguinalis* with respect to density and nutrient regime. The subdivisions in the columns represent the proportional allocations to various organs.

are included. The effect of various treatments on dry matter production showed a similar trend as in case of pure culture. However, *D. sanguinalis* in mixed culture had higher dry weight per plant at both medium and high density than in pure

Table 1. Seedling emergence (expressed as a percentage of the number of seeds sown) in pure stands of *Chenopodium album* and *Digitaria sanguinalis* under different density and nutrient regimes

Species	Nutrient regime					
	Low			High		
	Density					
	6	18	54	6	18	54
C. album	100.0	100.0	100.0	100.0	100.0	100.0
D. sanguinalis	100.0	96.3	92.6	100.0	95.6	94.5

Table 2. Effect of density and nutrient regime on seedling establishment(expressed as percentage of the number of seedling emerged) in pure stands of *C. album* and *D. sanguinalis*

Species	Nutrient regime					
	Low			High		
	Density					
	6	18	54	6	18	54
C. album	100.0	100.0	66.7	100.0	85.6	57.4
D. sanguinalis	100.0	88.9	53.7	100.0	74.3	42.6

culture(Fig. 1).

Energy allocation The number of seeds per plant of *D. sanguinalis* under different nutrient regimes was significantly reduced with increasing density($P<0.01$) but decreasing soil fertility($P<0.01$) in pure(Fig. 2a) and mixed(Fig. 2b) culture. Seed productions in mixed culture were markedly higher than in pure culture under both nutrient regimes. The proportion of total dry matter allocated to each organ of *D. sanguinalis* was shown in Fig. 3. In pure culture seed allocation decreased with increasing density under low nutient regime, but increased in high nutrient regime. In mixed culture was there an increasing tendency of seed allocating with increasing density under both nutrient regimes.

DISCUSSION

The population size of plants may be regulated either by a mortal response or plastic response. The mortal response can be expressed either as i) biological death, where the individuals are removed from populations, or ii) genetic death, where the individuals are able to survive but fail to produce effective propagules. Both the mortal and plastic response may be modified by both physical and biological components of the environment.

The probability of an emerged seedling surviving to maturity decreased with increasing density regardless of nutrient regimes. This mortal response was due to a limiting condition that cultivated pot size was very small. So, these results for seedling establishment were not coincident with those of Marshall and Jain(1969) and Pemadasa and Lovell(1974c). Their results showed that even seedling establishment in high density was more than 90%. Ultimately, the effect on the high density was resulted in similar with that of the medium density.

In mixed culture the performance of two species was clearly different. *D. sanguinalis* was remarkably effective in both dry matter and seed production with increasing density and high nutrients. Obviously it had a greater 'competitive advantage' than *C. album*.

Annual unpredictability of limiting resources can be a selective force favouring the plastic allocation of energy to seeds. Unless envirovmental conditions are very extreme, plants grown in harsh environment not only have higher reproductive allocation, but also produce more seeds per unit area(Hickman, 1975). Increasing of overall density could be considered as a kind of a stress, namely unfavourable environment in this experiment. Therefore, higher proportion of dry matter allocated to reproductive organs with increasing density could be regarded as a plastic response to density.

摘 要

一年生 草本인 명아주와 바랭이를 密度와 營養수준을 다르게 처리해 준 純栽培區와 混合

栽培區로 나누어 成長시켜, 그 競爭的인 效果를 밝히고 각 器官에 分配되는 에너지의 變化를 調査하였다.

두 種의 幼植物 出現은 密度와 營養수준에 關係없이 純栽培區 및 混合栽培區에서 모두 90% 이상으로 높게 나타났고, 植物體의 평균 乾重量은 높은 密度와 낮은 營養수준일수록 有意的으로 감소하였다.

바랭이는 명아주와의 交替栽培實驗(replacement series)에서, 높은 密度와 낮은 無機營養 수준에서 植物體의 乾重量과, 種子의 數로서 평가한 生殖器官으로의 分配도 이와 有似한 傾向을 나타냈다.

또한 바랭이는 種內競爭보다는 種間競爭에서 優勢하였고, 生殖器官에 分配되는 에너지는 遺傳的으로 決定되었다기 보다는 環境變化에 따른 彈力的 反應을 나타냈다.

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