Inter- and Intraspecific Variation in Smooth (*D. ischaemum*) and Large Crabgrass (*D. sanguinalis*)

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잔디밭 잡초 바랭이(*Digitaria* sp.)의 종내 및 종간 변이성

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ABSTRACT

A field trial was initiated to examine the range of inter- and intraspecific variations in morphological and phenological traits with five different accessions of smooth and large crabgrass. In addition, a controlled environment study was conducted to determine the phenotypic plasticity among the accessions of both species in response to 4 daily temperature differentials. In the field experiment, significant inter- and intraspecific variations of smooth and large crabgrass were observed in morphological traits such as leaf length and width. However, most phenological traits were not substantially different between the species and among the accessions of each species. The first seedling emerged at the same time, requiring 9~10 days, regardless of the accessions and species. In a controlled environment study, all accessions of each species responded similarly to the 4 temperature differentials in seedling emergence, indicating seedling emergence was not a plastic trait. These results suggest that predicting crabgrass seedling emergence could be independent of geographical regions in the US.

Key words: Crabgrass, phenotypic plasticity, prediction model, seedling emergence, tiller development, temperature differentials

Introduction

Crabgrasses, *Digitaria* spp. of the grass family (*Poaceae*), are seed-propagated summer annuals (Uva et al., 1997). Thirteen different crabgrass species occur in the United States, but smooth [*D. ischaemum* (Schreb.) Muhl] and large crabgrass [*D. sanguinalis*

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(L.) Scop.] are the most common (Mitich, 1988). Physiological and ecological competitiveness of these species has been related to C_4 photosynthetic pathway (Danneberger, 1993), enormous seed production (Peter and Dunn, 1971), and prostrate growth habit (Mitch, 1988). As a result of this, crabgrass threatens nearly all-cropping systems, especially turf areas in the United States (Kim et al., 1996).

There are several registered preemergence (Bhowmik, 1987; Johnson, 1995, 1996) and postemergence herbicides (Dernoeden et al., 1992; Johnson, 1994, 1996) available to control crabgrass in turf. The efficacy of these herbicides depends largely on application timing (Neal, 1994). Hence, predicting phenological events such as seedling emergence and tiller development is an important component for determining optimum timing of herbicide application. Peter and Dunn (1971) observed that the first seedling emergence of smooth and large crabgrass coincided with the flower withering of Forsythia or beginning of dogwood (*Cornus* sp.) flowers in the northern US. As modeling approaches, it has been reported that 5 to 7 consecutive days with daily mean soil temperature above 10℃ were normally required for large crabgrass seedling emergence in agricultural fields (Barret, 1981). Recently, a growing degree-day (GDD) model using soil mean temperature has been developed to predict smooth crabgrass seedling emergence in turf in the northeastern US. However, each model has been constructed in different geographical sites, and the utilization of this model has not been proven yet in the other US regions. Since intraspecific variations (Holt, 1988; Lush, 1989; Norris, 1996; Wang et al. 1995) and phenotypic plasticity (Caradus et al., 1993) of weed species has commonly been observed, a model constructed in a certain geographical region and cropping system may not be applicable in the different regions under variable environmental conditions.

The purpose of this study is to investigate inter- and intraspecific variations of the large and smooth crabgrass accessions from different geographical regions. Additionally, phenotypic plasticity of crabgrass was examined in response to daily temperature differentials. The results of this study could be useful in developing a more accurate and practical prediction model that integrates multiple ecological influences on crabgrass infestations in agricultural fields.

Materials and methods

Seed sources

Seeds of five accessions of smooth and large crabgrass were obtained from each different geographical region of the US during early 1995. These accessions consist of ITH (Ithaca, NY), LIR (Riverhead, NY), PSU (State College, PA), URI (Kingston, RI), CAD (Davis, CA), and the seeds were collected at regularly managed turf area in each location. Detailed location information is described in Table 1.

Table 1. *Meteorological details for the accessions of smooth and large crabgrass used in the study.*

Accession	Location		Elevation	Annual pre-	Temperature		
	Lat.	Long.	(m)	cipitation (cm)	Max	Min	Ave
ITH	Ithaca, NY 42° 27′ N	 76° 27′ W	295.7	89.6	13.3	2.3	7.8
LIR	Riverhead, NY 40° 58′ N	 72° 43′ W	30.5	115.1	16.0	6.5	11.2
PSU	State College, PA 40° 48′ N	 77° 52′ W	358.1	95.6	14.8	4.4	9.6
URI	Kingston, RI 41° 29′ N	 71° 32′ W	30.5	123.2	15.3	3.8	9.6
CAD	Davis, CA 38° 32′ N	 121° 46′ W	18.3	43.5	23.2	7.9	15.6

All accessions of both large and smooth crabgrass were harvested from regularly managed turf area of each location.
Data were obtained from Weather of US cities (Ruffner et al., 1985).

Since the obtained seeds were not evenly matured, each accession was grown in plastic 25-cm-diameter pots under a greenhouse condition of 30/25℃ (day/night) to harvest fully matured seeds. A soil medium (1 : 2 : 1 = loam soil : peat : perlite) amended with 5.8 kg super phosphate, 2.8 kg calcium nitrate and 2.8 kg potassium nitrate 1 m^{-3} was used. The pots of each accession were placed separately in the greenhouse to prevent cross-pollination. Fully matured seeds were collected and dried for 2 weeks at room temperature. To break seed dormancy, the collected seeds were prechilled at 4℃ for 2 months (Peter and Dunn, 1971; Toole and Toole, 1941). The seeds were then dried at room temperature for 1 month, and stored in a 4℃ refrigerator before use. After prechilling the seeds showed above 80 percent germination in a petri-dish test at 25℃ (data not shown).

Field study

A field experiment was conducted in summer of 1996 at the Cornell University Turfgrass Research and Education Center. The soil type at the study site was an Arkport fine sandy loam having a 2~6% slope. Soil pH was 5.1, organic matter was 3.0%, and P and K levels were 3.8 and 37 mg kg^{-1}, respectively. The area was cultivated and fumigated with metham (methylcarbamodithioic) 3-wk prior to sowing. One hundred seeds of each accession were sown in each plot (1×1 m) on 22 July 1996, and the plots were arranged in a randomized complete block design with 5 replications. Irrigation was supplied to maintain soil moisture for adequate growth during study period.

Emerged seedlings were counted every other day until no more germination occurred. Two weeks following the first emergence, the emerged seedlings were thinned to 10 seedlings for determining tiller development and relative growth rate. Tiller speed of each accession up to 5 tillers was monitored twice a week, and leaf width and length of 10 fully expanded leaves were measured at the 10^{th} tiller stage. Above ground relative growth rates, RGR_{above} (amount of dry matter production per unit of dry matter present per unit of time), were calculated according to the method of Kevt et al. as follows:

$$RGR_{above} = \ln W_2 - \ln W_1 / t_2 - t_1 \ (g\ g^{-1}\ day^{-1}) \quad [1]$$

Where W_1 and W_2 are the dry weight above ground plant biomass at the time t_1 and t_2, respectively. Above ground part of 3 plants in each plot was harvested at 20 and 35 days after seedling emergence, and dried in a oven at 50℃ for 5 days. Dry weight of each sample was then determined. The measured plant traits were defined as morphological, such as leaf length and leaf; and as phenological such as timing of seedling emergence and tiller development.

Growth chamber study

Growth chamber experiments were initiated in 1997 to determine the phenotypic plasticity of each crabgrass species in response to daily temperature differentials. Five 12-hr thermoperiods (and their daily temperature differentials) were 25/25℃ (0), 27.5/22.5℃ (5), 30/20℃ (10), 15/35℃ (20), and the daily mean temperature of each chamber was the same at 25℃. The photoperiod of each chamber was 12 hr, and the light intensity at pot level was 250 $\mu E\ m^{-2}\ sec^{-1}$ photosynthetic photon flux density (PPFD). The error for each temperature in each thermoperiod was ±1.5℃.

One hundred seeds of each accession were sown in a 10-cm-diameter plastic pot containing a soil medium (1 : 2 : 1 = loam soil : peat : perlite). Pots were arranged in a completely randomized design with 5 replications in each growth chamber and irrigated twice a day. Pot positions in each chamber were randomly rotated twice a week during the experiment to minimize micro-environmental effects. Emerged seedlings were counted every day, and each pot was thinned to 2 seedlings at 2 weeks after emergence for monitoring tiller development. Tiller development up to 5 tillers was then determined twice a week.

Statistics

Data were subjected to ANOVA for both field and growth chamber experiments. In the field study, means were separated by Fisher's protected LSD test at the 0.05 probability level, and a t-test was performed to determine the effect between species. In growth chamber experiments, the F-ratios were used to compare the magnitude of plasticity in each measured trait. Growth chamber experiments contained 5 replications were repeated once, and the pooled data of 10 replications were presented.

Results and Discussion

Inter- and intra-specific variation

Morphological traits

Significant morphological variations were observed between the species and among the accessions within each smooth and large crabgrass. Smooth crabgrass accessions showed significantly longer and narrower leaves compared to those of large crabgrass (Table 2), and this inter-specific variation is consistent with previous findings (Mitich, 1988; Peter et al., 1971; Uva et al., 1997). The plants with long and narrow leaves generally have high quantum efficiency (QUE) and water use efficiency (WUE) (Holt, 1994). Therefore, smooth crabgrass would have ecophysiological advantages in low light environments under plant canopy such as turfgrass. In addition, the smooth crabgrass accessions demonstrated more prostrate growth habits than large crabgrass (data not shown), suggesting that smooth crabgrass could be more tolerant to regular mowing practices in turf management systems. Consequently, these results suggest that smooth crabgrass could have more ecological advantages to be survived in turf areas than large crabgrass. It is also provide an explanation for the survey result (Kim et al., 1996), which indicated that smooth crabgrass is more problematic in turf areas than in the other cropping systems in the US.

Table 2. Inter- and intra-specific variation of large and smooth crabgrass in morphological traits.

Species/Accession	Morphological Traits	
	Leaf length (cm)	Leaf width (cm)
Large crabgrass		
ITH	12.1b	1.0a
LIR	7.8a	1.2a
PSU	10.8b	1.6b
URI	13.8b	1.5b
CAD	19.5c	1.7c
Significance[a]	***	***
Smooth crabgrass		
ITH	17.3b	0.9a
LIR	17.2b	0.9a
PSU	12.6a	1.2b
URI	18.0b	1.0a
CAD	21.4c	1.3b
Significance	***	***
t-test (between species)	***	***

[a]Significance at $P = 0.001$.
Similar letters within the column of each species indicate values that did not differ significantly between the means by Fisher's protected LSD at $P = 0.05$ level.

Within species, the CAD accessions of both species adapted to a relatively warm climate exhibited significantly bigger and wider leaves than the other accessions adapted to relatively low-temperature climates. This result implies that morphological traits of crabgrass species could be dependent upon regional climates, having the more robust leaf morphology in the accessions grown under the warmer-climate conditions.

Phenological traits

Not significant inter- and intraspecific variations of smooth and large crabgrass were observed in most phenological traits (Table 3), while it was significant in morphological traits. Timing of the first seedling emergence, days to 3 tillers, and flowering response were not substantially different in the accessions of each species. In particular, the first emergence time, a major trait considered in the prediction model, was consistent between the species

Table 3. Inter- and intra-specific variation of large and smooth crabgrass in several phenological traits.

Species/Accession	Phenological Traits			
	Emergence time (days[a])	Time to 3 tillers (days)	RGRabove (g g day-1)	Flower initiation (date[b])
Large crabgrass				
ITH	9.0	19.4a	0.16a	9/2
LIR	10.2	20.8a	0.19b	9/2
PSU	9.0	18.8a	0.14a	9/2
URI	9.0	23.2b	0.23b	9/2
CAD	9.0	18.9a	0.18a	9/2
Significance[c]	NS	*	*	NS
Smooth crabgrass				
ITH	9.0	19.4	0.20	-
LIR	9.0	20.8	0.21	-
PSU	9.6	18.8	0.19	-
URI	9.0	23.2	0.21	-
CAD	9.0	18.9	0.20	-
Significance	NS	NS	NS	N/A
t-test (between species)	NS	NS	**	N/A

[a]Days after overseeding.
[b]Dashes indicate that no fertile inflorescence developed on the plants.
[c]NS: non-significance at $P = 0.01$; **, *: significance at $P = 0.01$, 0.05, respectively.
Similar letters within the column of each species indicate values that did not differ significantly between the means by Fisher's protected LSD at $P = 0.05$ level.

and among the accessions of each species. Days to 3 tillers were significantly different at $P = 0.05$ among the accessions of large crabgrass, but the range of the variation was less than 5 days (Table 3). The mean values of RGR_{above} for large and smooth crabgrass accessions were 0.18 and 0.20 g/g · day respectively, resulting in smooth crabgrass could grow faster than large crabgrass during the growing season.

Interestingly, the flowering responses greatly differed between the two species during this study period (Table 3). Flowers of all large crabgrass accessions developed on September 2 of the late summer, but there was no floral initiation observed in any accession of smooth crabgrass. In a previous report (Throssell et al., 1993), both large and smooth crabgrass were defined as short-day plants, requiring less than a 10-hr photoperiod for their reproductive growth. However, the results from this experiment indicate that smooth crabgrass could require a shorter photoperiod for floral initiation than large crabgrass. It may be assumed that the distribution and adaptation of crabgrass species is geographically limited by day length, and smooth crabgrass could be more abundantly distributed and adapted in the northern areas with shorter day length than the southern areas.

Phenotypic plasticity to daily temperature differential

Table 3 showed F-values of an ANOVA using daily temperature differentials as a treatment effect. Each F-value then demonstrates the degree of plasticity for large and smooth crabgrass in response to the 4 temperature differentials. The extent of plasticity for each measured trait was varied in the accessions of both species. F-value for days to 3 tiller of large crabgrass was 53.8, and 36.8 for smooth crabgrass (Table 3), indicating that tiller development was the most plastic trait. However, the traits accounted for the prediction models such as timing of the first seedling emergence and emergence completion day appeared relatively low plastic traits in both species. The first seedling occurred at the same time in the all temperature differentials regardless of the accessions of each species, resulting in F-value 0.9 and 0.5 for large and smooth crabgrass, respectively. This result suggests that most phenological events, especially the first seedling emergence, could be independent of geographical regions with different temperature regimes.

Table 4. Degree of plasticity of plant characters in response to the temperature differentials.

Plant character	Species	
	DIGSA	DIGIS
	F-value[a]	
First emergence	0.9	0.5
Emergence Completion day	3.5	0.7
Days to 2 tillers	53.8	36.8

[a]F value from one-way analysis of variance using temperature differentials as treatment level (see materials and methods).

In conclusion, while significant inter- and intraspecific variations were observed in morphological traits, important phenological traits such as seedling emergence time and emergence completion day were not substantially different among the accessions of large and smooth crabgrass. Therefore, a model developed to predict crabgrass seedling emergence in a certain region and site could be considered for wide geographical use, particularly within the northeastern US.

요 약

잔디밭에 문제시되는 1년생 화본과 잡초인 바랭이(*Digitaria* sp.)의 종내 및 종간 변이성을 *D. ischaemum*과 *D. sanguinalis*의 5개 지역종을 대상으로 생육상과 포장조건에서 알아보았다. 포장실험결과 *D. sanguinalis*와 *D. ischaemum*의 종내 또는 종간의 잎의 길이와 폭 등을 포함한 형태적 형질에 관련된 유의한 변이성이 관찰되었다. 하지만, 표현형적 변이성에는 실질적 차이는 인정되지 않아 포장조건에서 최초발아시기는 종간 또는 지역종에 관계없이 동일하였다. 4가지의 주야간 온도 차이(25/25℃, 27.5/22.5℃, 30/20℃, 15/35℃)로 조절된 생육상 조건의 실험에서 각 바랭이 종의 발아소요일수에 관한 종간 또는 종내의 변이성은 없었다. 따라서, 잔디밭에서 효율적인 바랭이 방제를 위해 특정지역에서 최초 발아시기에 관련된 예측모델은 타 지역에도 동일하게 적용 가능할 것으로 생각된다.

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