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Notes

Response of Four Summer Annual Weed Species to Mowing Frequency and Height

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Greenhouse experiments were conducted in 2011 to evaluate the effect of mowing frequency and mowing height on four summer annual weed species (large crabgrass, barnyardgrass, giant ragweed, and common lambsquarters). Plants were clipped at three heights (5, 10, or 20 cm) and at two frequencies (single clipping or repeated clippings at the same height) to simulate mowing. A nonclipped control was also grown for each species. When clipped once, large crabgrass, barnyardgrass, and giant ragweed produced at least 90% of the total dry weight (DW) of the nonclipped plants, and common lambsquarters produced at least 75%. A single cut was generally not sufficient to prevent weed seed production or kill any of the weeds in this study. Repeated clipping reduced large crabgrass, giant ragweed, and common lambsquarters reproductive DW to 46, 27, and 10% respectively, of the nonclipped control. Barnyardgrass plants that were repeatedly clipped produced between 0 and 8% of the seed DW of nonclipped plants, depending on clipping height. Repeated clipping reduced weed total DW to below 40% for all species compared to nonclipped plants. Our results suggest that, unless combined with other weed management practices, repeated mowing may be necessary to limit the growth and seed production of these weed species.

Nomenclature: Barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. ECHCG; common lambsquarters, *Chenopodium album* L. CHEAL; giant ragweed, *Ambrosia trifida* L. AMBTR; large crabgrass, *Digitaria sanguinalis* (L.) Scop. DIGSA; velvetleaf, *Abutilon theophrasti* Medicus ABUTH.

Key words: Annual weeds; integrated weed management; mechanical control; plasticity.

En 2011, se realizaron experimentos de invernadero para evaluar el efecto de la frecuencia y altura de poda (i.e. chapia) en cuatro especies de malezas anuales de verano (*Digitaria sanguinalis*, *Echinochloa crus-galli*, *Ambrosia trifida*, y *Chenopodium album*). Las plantas fueron podadas a tres alturas (5, 10, ó 20 cm) y a dos frecuencias (poda única o poda repetida a la misma altura) para simular la chapia. También se incluyó un testigo sin poda para cada especie. Cuando se podó una vez, *D. sanguinalis*, *E. crus-galli*, y *A. trifida* produjeron al menos 90% del total del peso seco (DW) de las plantas sin poda, y *C. album* produjo al menos 75%. Generalmente, una sola poda no fue suficiente para prevenir la producción de semilla de malezas o matar a ninguna de las malezas en este estudio. La poda repetida redujo el DW reproductivo de *D. sanguinalis*, *A. trifida*, y *C. album* en 46, 27, y 10%, respectivamente, en comparación con el testigo sin poda. Las plantas de *E. crus-galli* que fueron podadas repetidamente produjeron entre 0 y 8% del DW de semillas en comparación con las plantas sin poda, dependiendo de la altura de poda. La poda repetida redujo el DW total por debajo del 40% en todas las especies al compararse con las plantas sin poda. Nuestros resultados sugieren que, a menos que se combine con otras prácticas de manejo de malezas, la poda o chapia repetida podría ser necesaria para limitar el crecimiento y la producción de semillas de estas especies.

Mowing is a relatively inexpensive form of mechanical weed control that does not disturb the soil and can be used to reduce tillage, herbicide use, and manual weeding (Bond and Grundy 2001; Donald 2000; Wehtje et al. 1999). Mowing between rows of no-till corn (*Zea mays* L.), soybean [*Glycine max* (L.) Merr.], and sorghum [*Sorghum bicolor* (L.) Moench] has been shown to reduce herbicide use by 50% and to prevent yield losses caused by weeds (Donald 2007a,b; Donald et al. 2001). Mowing between rows was also as effective at managing weeds as rototilling in corn and soybean (Donald 2000). In vegetable cropping systems, mowing a living mulch (red clover, *Trifolium pratense* L.) between rows was shown to improve hot pepper (*Capsicum annuum* L.) yields, but had no effect on okra (*Abelmoschus esculentus* Moench) yields (Biazzo and Masiunas 2000). Gibson et al. (2011) found that mowing a living mulch (buckwheat, *Fagopyrum esculentum* Moench) between tomato (*Lycopersicon esculentum* L.) rows after the critical weed control period suppressed weed seed production.

Mowing can be used to reduce weed populations over time. For example, a 6-yr field study in Maryland found that mowing plumeless thistle (*Carduus acanthoides* L.) at the full-bloom stage reduced plant densities compared to mowing at the full bud or postbloom stage (Tipping 2008). In the same study, musk thistle (*Carduus nutans* Wienm) declined only when mowed after the bloom stage (Tipping 2008). In an organic cropping system in Denmark, a suppressive cover-crop mixture (grass/white clover [*Trifolium repens* L.]) in combination with six mowing passes reduced Canada thistle

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by 69% within one growing season (Graglia et al. 2006). Bicksler and Masiunas (2009) conducted a field experiment in Illinois evaluating the combined effect of mowing and summer annual cover crops on Canada thistle growth. They found that mowing sudangrass [*Sorghum sudanense* (Piper) Stapf.] alone or in a mixture with cowpea [*Vigna unguiculata* (L.) Walp] reduced Canada thistle shoot density and mass to less than 20% of initial shoot and mass compared to buckwheat or fallow treatments. Lower densities of Canada thistle were observed in the subsequent growing season, suggesting the mowing and competition from cover crops had a lasting effect.

Weed species vary in their response to mowing frequency and mowing height. Patracchini et al. (2011) repeatedly cut common ragweed (*Ambrosia artemisiifolia* L.) at 20, 50, and 80 cm in field experiments in Italy. When common ragweed was cut three times at 20 cm, mortality ranged from 25 to 33%; however, nearly all of the surviving plants were able to flower. In greenhouse experiments, Andreasen et al. (2002) cut catchweed bedstraw (*Galium aparine* L.), common hempnettle (*Galeopsis tetrahit* L.), wild buckwheat (*Polygonum convolvulus* L.), and wild oat (*Avena fatua* L.) at 5 and 8 cm. Plants cut at 8 cm produced more biomass than the uncut control, and up to four times the biomass of plants cut at 5 cm. Crabgrass (*Digitaria* spp.) dry weight (DW) was reduced 85% in Kentucky bluegrass (*Poa pratensis* L.) and tall fescue (*Festuca arundinacea* L.) turf when mowed repeatedly at 4 to 8 cm (Busey 2003). However, mowing the turf grasses below 4 cm limited their ability to compete with crabgrass.

Donald (2006) suggested that the use of mowing to control weeds has not been well studied by weed scientists. More research is needed to determine how summer annual weed species respond to mowing frequencies and mowing heights. In this study, we simulated mowing by clipping five summer annual weed species at different heights and frequencies. We hypothesized that (1) taller plants would be less affected by clipping frequency than shorter plants and (2) clipping plants once would not be sufficient to kill weeds regardless of clipping height.

Materials and Methods

A greenhouse study was conducted to assess the effect of mowing height and frequency on the growth of four common summer annual weeds: large crabgrass, barnyardgrass, giant ragweed, and common lambsquarters. The first experiment was initiated on February 9, 2011 and ended May 16, 2011; it was replicated starting on July 1, 2011 and ending on September 21, 2011 in West Lafayette, IN (40.42°N, 86.91°W). A randomized complete block design with four blocks and three main treatments (weed species, clipping height, and clipping frequency) was used. Clipping heights were 5, 10, or 20 cm, and plants were clipped once and allowed to regrow or clipped repeatedly to maintain heights. Initial clippings did not take place until plants were 2 cm above each treatment mowing height. A control treatment in which plants were not cut was included.

Plants were grown with supplemental lighting to simulate Indiana summers of 14-h days and 10-h nights. Greenhouse temperatures were recorded daily, and minimum and maximum temperatures were 19 C ± 0.2 standard error (SE) and 37 C ± 0.5 SE in the first experiment and 22 C ± 0.4 SE and 35 C ± 0.5 SE in the second experiment, respectively. Seeds from each species were sown into pots (16 cm in diameter and 18 cm in depth) containing 2,200 g of air-dried Gifford sandy loam soil (coarse–loamy, mixed, superactive, mesic Typic Endoaquolls). Plants were thinned to one per pot after emergence and fertilized with 7.9 kg m^{-2} of a 10-52-10 starter fertilizer (Miracle-Gro® Water Soluble Bloom Booster, Scotts Miracle-Gro Products, Inc., Marysville, OH 43041) as recommended for transplanted crops in the Midwest (Egel 2012). Plants were watered daily and height was measured weekly to determine if plants needed to be cut. Plants were harvested when nonclipped plants for all species had produced seed, i.e., at 96 and 80 d after sowing (DAS) in the first and second experiments, respectively. Harvested plants were separated into leaves, shoots, roots, and seeds (inflorescences if seeds were immature), dried at 60 C until constant weight was reached, and weighed.

A mixed-model ANOVA was used to test the effect of the independent variables and their interaction on plant growth with the PROC MIXED procedure with the use of the SAS 9.2 software package (SAS Institute, Inc., Cary, NC). Mowing height and frequency were treated as fixed effects and experiment and block as random effects. Treatment means were compared using Fisher's Protected LSD at $P = 0.05$. Weed species were analyzed separately, because there were significant interactions between species and other treatments. When interactions occurred, clipping height and clipping frequency were analyzed separately. Data were pooled across experiments if no interaction between experiment and treatment were present. Data were transformed to meet normality and heterogeneity assumptions as needed, but untransformed data are presented.

Results and Discussion

Large Crabgrass. Large crabgrass plants clipped at 5 cm had lower root, leaf, and total DW than plants cut at 20 cm (Table 1). Differences in panicle DW were not detected among the mowing-height treatments (Table 1). Plants clipped repeatedly had lower leaf, panicle, and total DW than plants clipped only once (Table 1). Root DW was not affected by clipping frequency (Table 1). Differences in shoot DW were not detected among mowing-height treatments in the first experiment (data not shown), but were detected between the 5-cm treatment (52% ± 12.7 SE) and the 10-cm (84% ± 7.4 SE) and 20-cm (88% ± 5.0 SE) treatments in the second experiment. Shoot DW was higher in both experiments for plants cut once (74% ± 5.7 SE and 67% ± 5.4 SE of uncut controls in the first and second experiments, respectively) than for plants cut repeatedly (27% ± 6.4 SE and 13% ± 3.2 SE in the first and second experiments, respectively). In general, the prostrate growth form of large crabgrass allowed it to spread horizontally and avoid clipping. Large crabgrass plants clipped once produced 85% or more of the biomass of plants that were never clipped (Table 1). Even plants that were repeatedly clipped produced 72% of the total

Table 1. Effect of clipping height and frequency on large crabgrass dry weight (DW) grown under greenhouse conditions in 2011.[a] Plants were clipped once or repeatedly at three different heights. Data are expressed as a percentage of unclipped control plants. Values are means; parentheses enclose standard errors. Within each treatment (clipping height or frequency), means followed by the same letter were not significantly different at $P \leq 0.05$.

		Clipping height			Clipping frequency	
	Control	5 cm	10 cm	20 cm	Single cut	Repeated cuts
	g plant^{-1}	Percentage of control (%)				
Root DW	17 (3.6)	59 (10.5) b	78 (11.0) ab	110 (19.0) a	90 (11.5) a	75 (12.6) a
Leaf DW	9 (0.8)	59 (9.7) b	77 (7.4) ab	91 (5.2) a	85 (6.6) a	66 (6.3) b
Panicle DW	3 (0.6)	64 (16.2) a	106 (25.0) a	80 (10.8) a	121 (16.3) a	46 (8.6) b
Total DW	59 (4.6)	67 (9.0) b	81 (7.1) ab	97 (6.2) a	91 (5.7) a	72 (6.8) b

[a] Interaction was detected between clipping height and experiment for shoot DW and shoot DW was analyzed separately for each experiment.

DW and 46% of the panicle DW of plants that were never clipped (Table 1).

Barnyardgrass. Barnyardgrass root, leaf, and total dry weights were lower for plants clipped at 5 cm than for plants clipped at 10 or 20 cm. Differences in root DW, leaf DW, and total DW were not detected between the 10- and 20-cm treatments (Table 2). Clipping barnyardgrass once did not reduce total DW relative to the control, but repeated cuts reduced barnyardgrass total DW to 18% of the noncut control (Table 2). An interaction between mowing height and frequency was detected for shoot and panicle DW. Shoot DW was lower for plants cut once at 5 cm (72% ± 11.1 SE) than for plants cut once at 10 cm (135% ± 17.1 SE). No differences were detected when plants were clipped once at 10 cm or at 20 cm (113% ± 16.2 SE). Differences in shoot DW were detected among plants cut repeatedly at 5 (2% ± 0.5 SE), 10 (17% ± 6.1 SE), and 20 cm (40% ± 9.7 SE). No differences in panicle DW were detected among clipping heights when plants were clipped once. However, plants cut repeatedly at 5 cm did not produce panicles. Differences in panicle DW were not detected when plants were cut repeatedly at 10 cm (3% ± 2.7 SE) or at 20 cm (8% ± 3.4 SE).

Giant Ragweed. Giant ragweed plants that were clipped once produced 96% ± 6.4 SE of the total DW and 110% ± 15.7 SE of the seed DW of plants that were not cut (Table 3). Although giant ragweed typically produces a single shoot, it can produce multiple shoots from axillary meristematic tissue if apical dominance is lost (Brabham et al. 2011; Mager et al. 2006). Giant ragweed plants cut once or repeatedly in our experiment produced multiple shoots. However, plants that were repeatedly cut produced only 38% of the total DW and 27% of the seed DW of uncut plants (Table 3). Giant ragweed root and total DW were greater for plants cut at 20 cm than for plants cut at 5 cm and 10 cm (Table 3). Interaction between clipping height and frequency was detected for shoot dry weight. Plants clipped once produced more shoot dry weight than plants clipped repeatedly at 5 cm (105% ± 14.4 SE and 14% ± 6.4 SE, respectively) and at 10 cm (102% ± 12.0 SE and 23% ± 3.6 SE, respectively) but differences were not detected at 20 cm (111% ± 17.3 SE and 83% ± 12.4 SE, respectively). There was no mowing-frequency by clipping-height interaction detected for leaf DW, but interaction was detected between experiment and mowing treatments. Leaf DW was greater for plants clipped at 20 cm than at 5 or 10 cm in the second run, but differences in leaf DW were only detected between the 20- and 10-cm treatments in the first run (Table 3). Leaf DW for plants repeatedly cut was 25% or less of uncut plants and differences in leaf DW were detected between plants cut once and those cut repeatedly in both runs (Table 3).

Common Lambsquarters. Common lambsquarters root and total DW were greater for plants cut at 20 cm than for plants cut at 10 or 5 cm (Table 4). Shoot DW was greater for plants cut at 20 cm than for plants cut at 5 cm. No differences were found between the 5- and 10-cm treatments. Inflorescence DW did not vary among clipping-height treatments (Table 4). Plants that were cut repeatedly produced only 10% of the inflorescence DW of the control plants and only 21% of the total DW (Table 4). Cutting plants once had little effect on inflorescence DW (Table 4); total DW was reduced by 25% when plants were cut once (Table 4). No differences in leaf DW were detected for plants cut once at 5 (78% ± 15.4 SE), 10 (54% ± 6.9 SE), or 20 cm (64% ± 8.1 SE), but plants cut repeatedly at 20 cm had more DW (31% ± 7.8 SE) than

Table 2. Effect of clipping height and frequency on barnyardgrass DW grown under greenhouse conditions in 2011.[a,b] Plants were clipped once or repeatedly at three different heights. Data are expressed as a percentage of unclipped control plants. Values are means; parentheses enclose standard errors. Within each treatment (clipping height or frequency), means followed by the same letter were not significantly different at $P \leq 0.05$.

		Clipping height			Clipping frequency	
	Control	5 cm	10 cm	20 cm	Single cut	Repeated cuts
	g plant^{-1}	Percentage of control (%)				
Root DW	11 (1.6)	30 (8.4) b	70 (16.8) a	82 (18.1) a	96 (12.4) a	25 (8.67) b
Leaf DW	7 (0.7)	34 (9.7) b	55 (14.6) a	63 (10.6) a	89 (7.8) a	13 (3.3) b
Total DW	44 (6.1)	36 (10.1) b	65 (14.9) a	74 (13.0) a	99 (8.3) a	18 (4.9) b

[a] Interaction was detected between mowing height and frequency for shoot dry weight and between mowing height and frequency for panicle dry weight.

[b] Abbreviations: DW = dry weight.

Table 3. Effect of clipping height and frequency on giant ragweed dry weight (DW) grown under greenhouse conditions in 2011.[a] Plants were clipped once or repeatedly at three different heights. Data are expressed as a percentage of control plants, which were not clipped. Values are means; parentheses enclose standard errors. Within each treatment (clipping height or frequency), means followed by the same letter were not significantly different at $P \leq 0.05$.

		Clipping height			Clipping frequency	
	Control	5 cm	10 cm	20 cm	Single cut	Repeated cuts
	g plant^{-1}	Percentage of control (%)				
Root DW	9.3 (2.2)	54 (12.6) b	56 (8.6) b	139 (18.7) a	109 (13.7) a	56 (11.8) b
Leaf DW (E1)[b]	7.4 (0.3)	49 (13.6) ab	38 (11.9) b	65 (13.6) a	77 (7.5) a	24 (7.2) b
Leaf DW (E2)	6.6 (0.6)	36 (9.2) b	36 (7.3) b	59 (7.6) a	62 (4.3) a	25 (4.9) b
Seed DW	1.2 (0.3)	66 (21.6) a	80 (21.0) a	86 (22.0) a	110 (15.7) a	27 (9.5) b
Total DW	26.8 (3.5)	55 (10.1) b	52 (8.8) b	96 (10.2) a	96 (6.4) a	38 (6.6) b

[a] Interaction between clipping height and frequency was detected for shoot dry weight and between experiment and clipping treatments for leaf DW.

[b] Leaf DW analyses are presented separately for each experiment. Abbreviations: E1, first experiment; E2, second experiment.

plants cut at 10 (12% ± 2.2 SE) or 5 cm (5% ± 1.4 SE). Reducing common lambsquarters infloresence DW required repeated clipping; a single clipping had little effect on common lambsquarters growth regardless of clipping height.

Differences in root and total DW were detected between the 5- and 20-cm clipping levels for all four species. Clipping the broadleaf species at 10 cm reduced their root and total DW relative to clipping them at 20 cm (Tables 3 and 4). However, grass species produced as much root and total DW when clipped at 10 cm as at 20 cm (Tables 1 and 2). Differences in reproductive DW (panicles, seed, inflorescences) were not detected among clipping heights for large crabgrass, giant ragweed, or common lambsquarters (Tables 1, 3, and 4). Interaction between clipping height and frequency was only detected for barnyardgrass panicle DW. No differences in barnyardgrass panicle DW were detected when plants were cut repeatedly between the 10- and 20-cm levels, but panicles were not produced when plants were repeatedly cut at 5 cm. Therefore, with the exception of barnyardgrass, our hypothesis that taller plants would be less affected by clipping frequency was not supported.

Weed species can respond to mowing with changes in biomass partitioning, tiller production, branching, and photosynthetic rates that allow compensatory growth (Li et al. 2004; Monaco et al. 2002). Weeds clipped only once in our study were generally able to produce as much total DW and seed DW as plants that were never clipped. Plants were clipped relatively early in their growth; it is possible that clipping plants once near anthesis could result in a greater reduction in seed production. However, it may be difficult to time mowing operations to coincide closely with weed phenology, because relatively small delays in mowing might enable weed seed production. Cutting plants repeatedly (plants were cut between five and eight times depending on species and clipping height) reduced the total DW of all species except large crabgrass by between 62 and 82%, and reduced seed DW by between 63 and 99%. Barnyardgrass and common lambsquarters seed production was particularly affected by repeated clipping; both species produced less than 10% of the seed DW of nonclipped plants. Although repeated mowing appears to have potential for limiting weed growth and seed production, it seems unlikely that growers would adopt a strategy that requires so many mowing passes. To reduce the need for multiple passes, mowing could be combined with other management practices to cumulatively provide weed control. Donald (2007a) found that giant foxtail (*Setaria faberi* Herm.) could be controlled by mowing twice between rows of corn. Giant foxtail regrew from tiller buds after the first mowing pass, but not after the second pass. The author suggested that shading by the corn canopy after the second mowing pass likely contributed to giant foxtail control. Similarly, Renz and DiTomaso (2006) found that perennial pepperweed (*Lepidium latifolium* L.) control was improved when mowing was followed by herbicide application.

Mowing can reduce tillage, herbicide use, and manual weeding, but relatively little research has been conducted on the use of mowing in crops (Bond and Grundy 2001; Donald 2000, 2006; Wehtje et al. 1999). Weeds used in this study recovered from a single clipping, but repeated clippings

Table 4. Effect of clipping height and frequency on common lambsquarters DW grown under greenhouse conditions in 2011.[a,b] Plants were clipped once or repeatedly at three different heights. Data are expressed as a percentage of unclipped control plants. Values are means; parentheses enclose standard errors. Within each treatment (clipping height or frequency), means followed by the same letter were not significantly different at $P \leq 0.05$.

		Clipping height			Clipping frequency	
	Control	5 cm	10 cm	20 cm	Single cut	Repeated cuts
	g plant^{-1}	Percentage of control (%)				
Root DW	5 (0.8)	51 (12.1) b	56 (8.6) b	87 (13.3) a	90 (9.9) a	39 (6.3) b
Shoot DW	14 (0.7)	37 (8.8) b	42 (6.8) ab	56 (7.6) a	70 (3.9) a	20 (3.8) b
IDW	3 (0.4)	43 (13.4) a	63 (22.2) a	56 (16.5) a	97 (15.6) a	10 (3.2) b
Total DW	31 (1.2)	41 (9.8) b	44 (7.2) b	59 (7.3) a	75 (4.0) a	21 (3.6) b

[a] Interaction was detected between clipping height and frequency for percent leaf dry weight.

[b] Abbreviations: DW, dry weight; IDW, inflorescence dry weight.

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substantially reduced total plant and seed DW for all species except large crabgrass. The differential response of large crabgrass suggests that a weed management strategy that relied heavily on mowing might select for more large crabgrass. However, this research was conducted under greenhouse conditions and weeds grew without competition, limiting our ability to extrapolate to field conditions. Further research on the use of mowing to manage weeds in crops appears warranted.

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