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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 400 projects at a cost of $31 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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USGA Turfgrass and Environmental Research Committee

Competitive Effects of Various Weed Species on Seeded Zoysiagrass Establishment

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SUMMARY

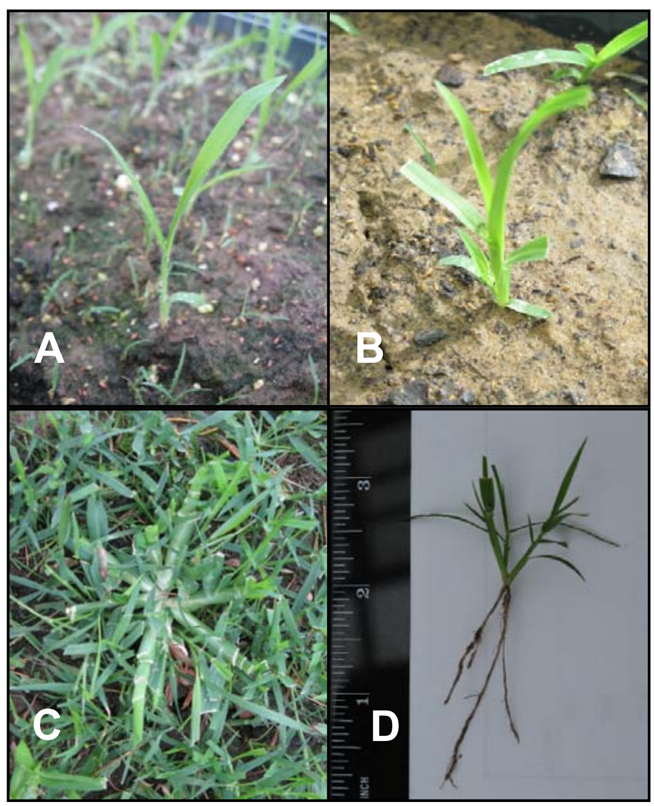
Weed competition during seeded establishment often inhibits turfgrass development, thus producing a poor turfgrass stand. The result of weed competition may be affected by management practices, weed density, and weed species present. Currently, little is known about how specific weed species compete with turfgrasses during early developmental stages. Additive competition experiments were conducted at Auburn University in 2008 and 2009 to determine the competitive effects of smooth crabgrass and goosegrass on 'Zenith' zoysiagrass establishment. Experimental data indicate:

- Weed species and density do not affect number of germinating zoysiagrass seedlings, but these factors do significantly impact maturation and dry matter yield of seeded zoysiagrass 8 weeks after seeding.
- Across all densities evaluated, zoysiagrass grown with smooth crabgrass resulted in a greater percentage of tillering plants compared to when zoysiagrass was grown with goosegrass.
- Zoysiagrass dry matter yield loss (per weed unit and maximum loss) was greater for goosegrass compared to smooth crabgrass.

In agricultural and turfgrass systems, the negative effect of weeds on crop yield and aesthetics is of utmost importance. Weeds compete with new plantings for light, nutrients, moisture, and space (18). Summer annual grassy weeds such as crabgrass (*Digitaria* spp.) and goosegrass [*Eleusine indica* (L.) Gaertn.] germinate in late spring to early summer at the same time that is recommended for the establishment of warm-season grasses such as zoysiagrass in the southeastern United States (1, 21).

Rapid establishment of a turfgrass is desirable to reduce weed colonization, reduce potential erosion problems, and minimize disruption of play. Unfortunately, zoysiagrass is relatively slow to establish vegetatively or by seed (7, 16). Literature indicates that cultural practices such as seeding rate and nitrogen fertilization have minimal impact on zoysiagrass establishment rates (8, 13, 21, 22, 24). Since competition with summer annual weeds is known to reduce establishment, weed control is essential for optimal establishment of zoysiagrass (8, 12).

Plant-plant interactions experienced by individuals in heterospecific communities are complex. Much of what is known about the competitive ability of plant species is learned from a comparison of their relative competitiveness with one another in varying environments (14, 32). Competition may occur between individuals of the same species (intraspecific) or different species (interspecific). Additionally, competition



Smooth crabgrass seedling (A), goosegrass seedling (B), mature goosegrass plant (C), and zoysiagrass seedling (D).

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may be divided into above- and below-ground since plants use different structures to compete for different resources (6, 19). As a result of this complexity, quantifying and interpreting plant-plant interactions has been problematic for agronomists and ecologists.

The result of crop-weed competition may be affected by management practices, duration of competition, weed species present, and weed density (9). In crop production systems, numerous studies have evaluated the effect of individual weed species on crop yield (2, 3, 17, 26, 28, 29). Many indices have been developed that rate the competitiveness (the ability to reduce crop yield) of weed species (31). Furthermore, the model of an economic threshold has been well-defined in agricultural crops as a function of weed density, cost of treatment, yield loss caused by each weed unit, and efficacy of treatment (25, 27). In contrast to agricultural crops, managed turfgrasses are typically rated using visual assessment (color, quality, and texture) and therefore there is no true yield component that is reduced by the presence of weeds (4, 15). As a result, competition indices ranking various weed species have not been developed for turfgrass systems.

Little is known about how weed species compete with turfgrasses during early developmental stages. Understanding how specific weed species compete with turfgrasses during establishment will contribute to our overall knowledge of turfgrass growth and ecology. The objective of this research was to determine the competitive effects of smooth crabgrass [*Digitaria ischaemum* (Schreb. ex Schweig) Schreb. ex Muhl.] and goosegrass on 'Zenith' zoysiagrass (*Zoysia japonica* Steud.) establishment.

Materials and Methods

Competition studies were initiated in winter 2008 and 2009 at the Auburn University Weed Science greenhouse in Auburn, AL. The experiment was an additive design with three replications per experimental run (11, 23). Experimental units were 1.4-ft^2 greenhouse flats. A Wickham sandy-loam (fine, loamy, siliceous, subactive, thermic Typic Hapludult), pH 6.1 was steam sterilized and subsequently mixed with Pro-mix at 5:1 (soil:Pro-mix) to restore soil structure and water holding capacity. 'Zenith' zoysiagrass seeding rate was constant at 1 lb/1,000 ft^2 pure live seed (PLS) while weeds (neighbor species) per unit area increased.

Neighbor seeding rate was based on seed weight and germination percentage. Smooth crabgrass seed was obtained from Estel Farm and Seeds, while goosegrass seed was collected from local populations. Treatments included: zoysiagrass alone (monoculture) and zoysiagrass plus 61, 185, 395, 674, or 898 neighbor plants (PLS) per experimental unit. These densities represent plant counts from preliminary studies using neighbor seeding rates of 0.1 to 1.0 lb/1,000 ft^2. Due to poor goosegrass germination in the second year, only one experimental run was conducted using goosegrass in these studies.

Greenhouse flats were fertilized with a

Effect	Zoysia total[a]	Leaf[b]	Tiller 1	Tiller 2
	P-value			
Neighbor	0.313	0.149	<0.001	0.002
Density	<0.001	<0.001	<0.001	<0.001
Neighbor x Density	0.541	0.015	0.085	<0.001

[a]Zoysia total represent number of zoysiagrass plants in one 16-in^2 sample.

[b]Developmental stages represent zoysiagrass plants with no tillers (leaf), one to four tillers (tiller 1) or five to eight tillers (tiller 2).

Table 1. Analysis of variance for fixed effects of total number of zoysiagrass plants, percent of plants in leaf, tiller 1, and tiller 2 stage 8 weeks after seeding with smooth crabgrass or goosegrass.

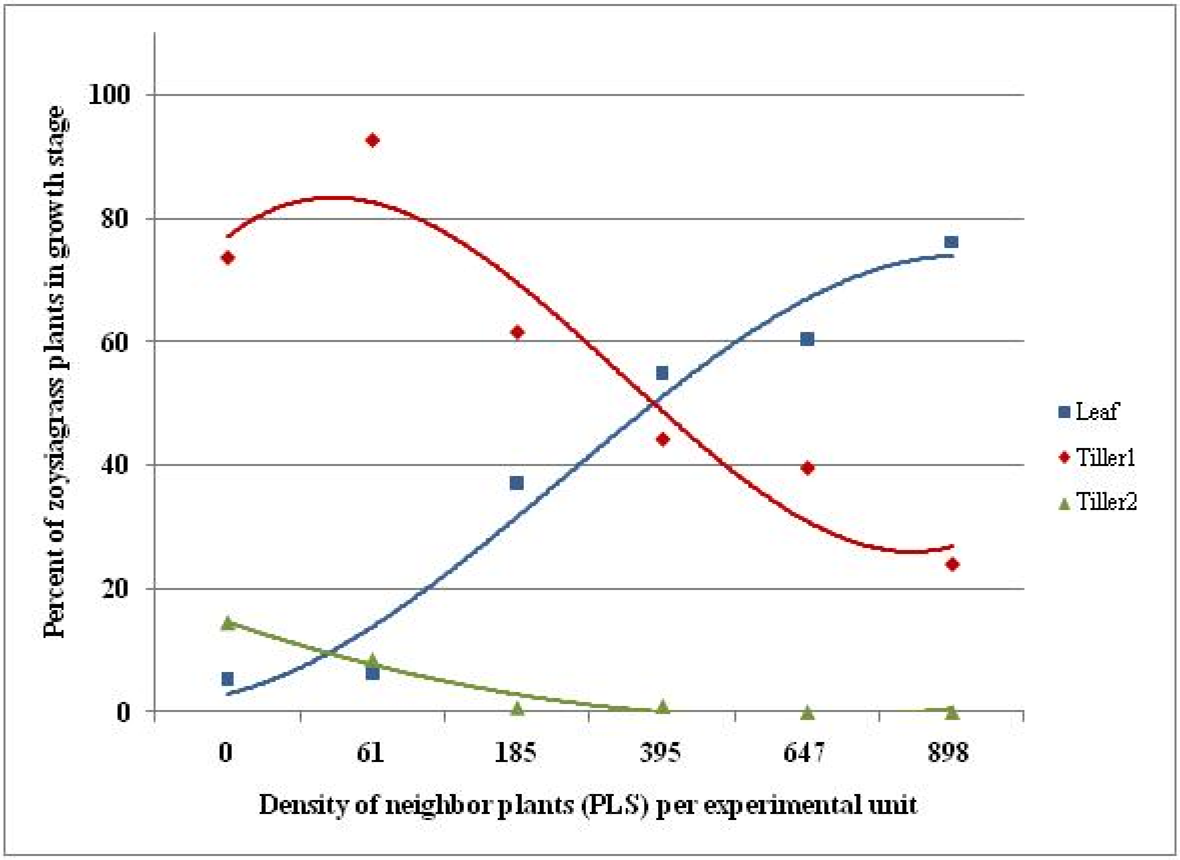

Figure 1. 'Zenith' zoysiagrass developmental response to increasing smooth crabgrass density 8 weeks after seeding. Symbols are least square means; lines are fitted values.

commercial fertilizer 24-8-16 (N-P-K) every 2 weeks and were maintained at a mowing height of 1.25 inches using hand-held grass shears throughout each study.

Data Collection and Analysis

Data collected from each experiment included: (i) plant counts and developmental stage measurements at 2, 4, 6, and 8 weeks after seeding (WAS) from two 16-in^2 samples per flat, and (ii) dry weights of above-ground tissue harvested 8 WAS. Three categories of zoysiagrass development stage were organized: "leaf stage" represented by one-to-three-leaf plants (no tillers present); "tiller 1" represented by one-to-four-tiller plants; and "tiller 2" represented by five-to-eight-tiller plants. A tiller was defined as the initial plant plus any aerial shoots emerging from axillary buds or a shoot emerging from stolons (18).

Developmental stage counts were converted to percent of total zoysiagrass population using the following formula:

$$\text{\% in growth stage} = \left(\frac{\text{(\# of plants in stage A)}}{P_{total}}\right) \text{X } 100$$

where stage A = leaf, tiller 1, or tiller 2, and P_{total} = total number of zoysiagrass plants in one 104-cm^2 sample. Above-ground zoysiagrass plant tissue was harvested from one 16-in^2 sample per experimental unit 8 WAS. Plant material was placed into a forced air dryer for 72 hours at 60° C before weighing. Zoysiagrass dry weight measurements were converted to percent yield loss using the formula:

$$Y_L = \left(\frac{1-Y_i}{Y_{WF}}\right) \text{X } 100$$

where Y_L is percent yield loss, Y_i is yield of a plot, and Y_{WF} is the average yield of a weed-free plot within each rep.

The relationship of weed density to crop yield has been described using a rectangular hyperbola model (10). This model contains several biologically meaningful parameters that allow the researcher to account for the effect of weeds at low and high densities and subsequently use parameter estimates to rank the competitiveness of different weed species (10). Zoysiagrass dry-matter yield loss data were fit to the rectangular hyperbola model implemented in SAS® PROC NLIN. The rectangular hyperbola model is:

$$Y_L = \frac{Id}{(1 + Id/A)}$$

where Y_L is percent yield loss, I is percent yield loss per unit weed density as d approaches zero, d is weed density, and A is percent yield loss as d approaches infinity. Data were subjected to ANOVA to determine the effect of neighbor species, density, and neighbor by density interaction. Because zoysiagrass plants did not attain mature developmental stages (tiller 1 and tiller 2) until 6 weeks after seeding, data discussed herein were taken 8 weeks after seeding.

Results and Discussion

Neighbor species (crabgrass or goosegrass) was significant for tiller 1 and tiller 2 development stage, but was not significant to total zoysiagrass plant count. Neighbor seeding density and neighbor by density interaction was significant for all developmental stages (Table 1).

Zoysiagrass Development

Zoysiagrass development was reduced at all seeding densities by both weed species (Figures 1 and 2). Zoysiagrass development was similar among the monoculture and the lowest neighbor density of 61 PLS per experimental unit. However, percentage of zoysiagrass population in

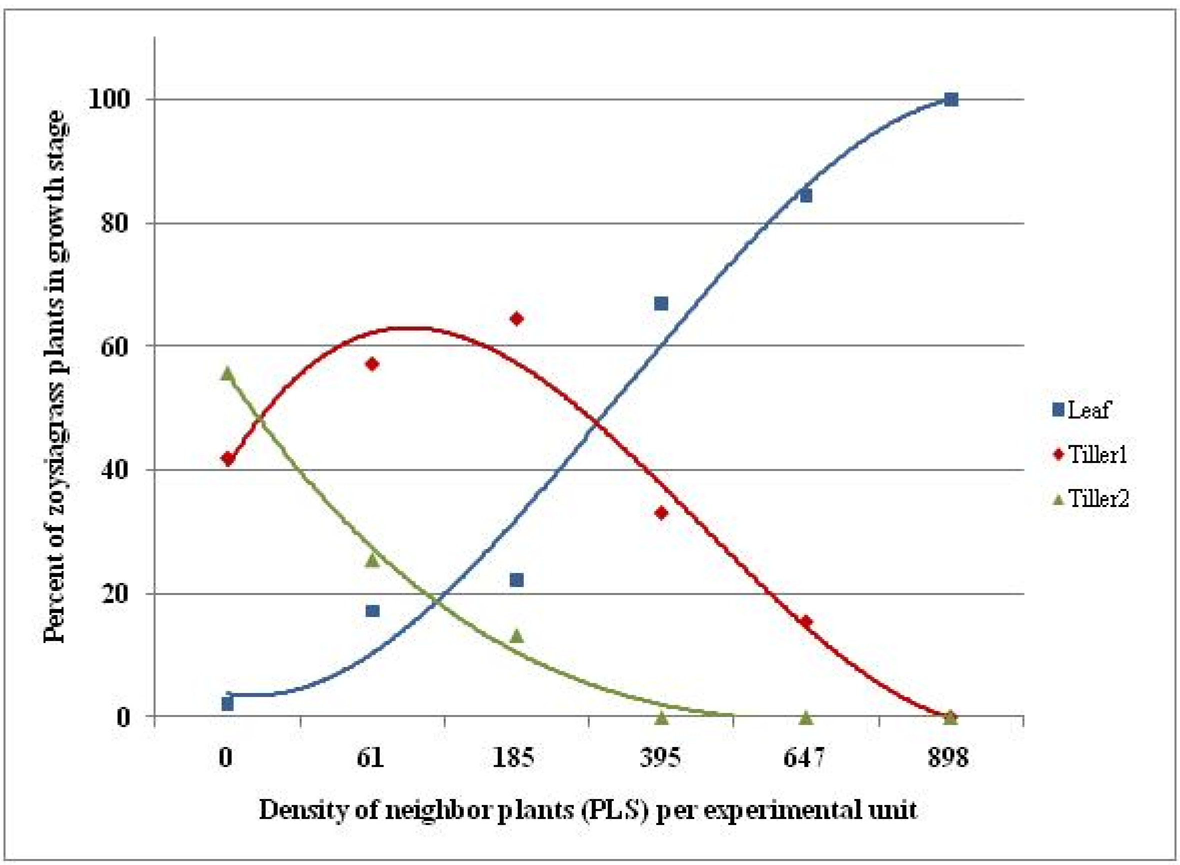

Figure 2. 'Zenith' zoysiagrass developmental response to increasing goosegrass density 8 weeks after seeding. Symbols are least square means; lines are fitted values.

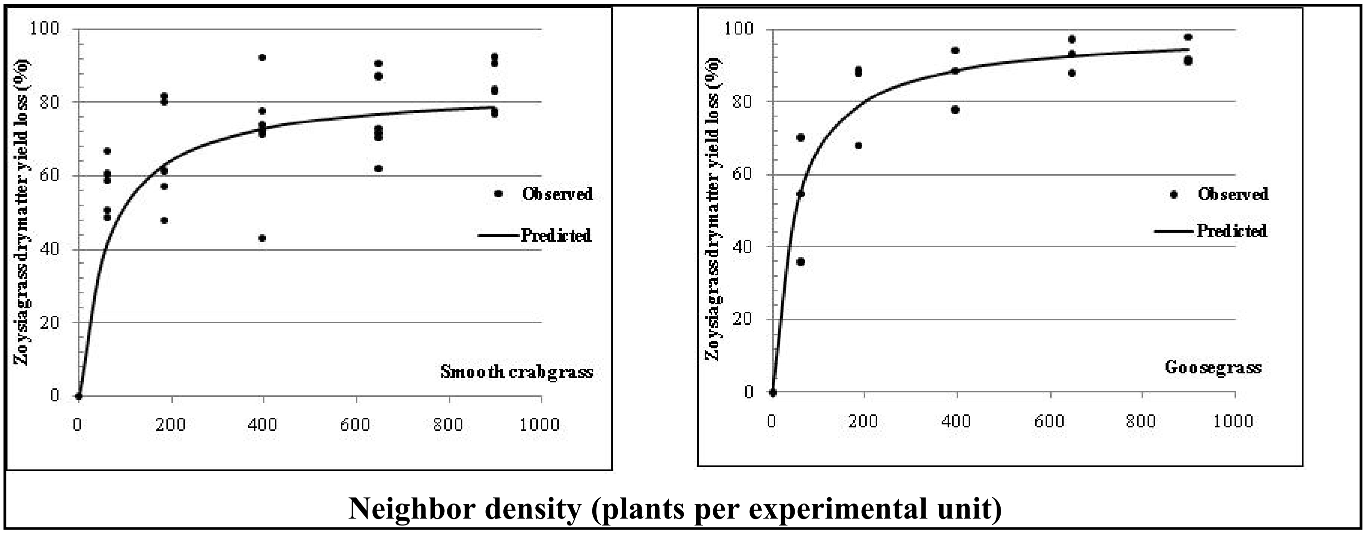

Figure 3. 'Zenith' zoysiagrass dry matter yield loss as a function of neighbor density. Lines are the fitted hyperbolic equation with parameter estimates given in Table 2.

the leaf stage (no tillers present) progressively increased with increasing neighbor density (Figures 1 and 2). Under competition with smooth crabgrass or goosegrass (395 PLS per experimental unit), zoysiagrass populations were comprised of approximately 60% leaf stage in comparison to less than10% leaf stage in zoysiagrass monocultures.

This is similar to an early report by Gardner (14) where tillering of six grass species was reduced in mixed species plots compared to single species plots. Although neighbor species itself was not significant (P = 0.149) to percent of zoysiagrass plants in leaf stage, significant neighbor by density interaction (P = 0.015) was evident, particularly at the highest neighbor density of 898 PLS per experimental unit. At this neighbor density, zoysiagrass populations were comprised entirely of non-tillering plants when grown with goosegrass (Figure 2), whereas more than 20% of zoysiagrass plants developed tillers when grown with smooth crabgrass (Figure 1).

An inverse relationship was observed between leaf stage and tiller 1 zoysiagrass development in these studies. Therefore, as leaf stage became the predominant developmental stage, percentage of zoysiagrass plants in tiller 1 stage decreased. Analogous to leaf stage plant counts, percent zoysiagrass plants in tiller 1 developmental stage was similar among the monoculture and neighbor seeding densities of 61 and 185 PLS per experimental unit. This may indicate a competitive level at which zoysiagrass development is not inhibited.

Neighbor species, density, and neighbor by density interaction effects were significant to tiller 1 development (Table 1). Comparing the two neighbor species across all densities evaluated, zoysiagrass grown with smooth crabgrass resulted in a greater percentage of tiller 1 plants than when grown with goosegrass. In particular, smooth crabgrass permitted more than 20% tiller 1 development at the highest neighbor density, whereas goosegrass eliminated this developmental stage entirely (Figure 2).

Tiller 2 developmental stage was not a major constituent of zoysiagrass populations in these studies. This is most likely due to the slow growth rate and establishment of zoysiagrass species, indicating that greater than 8 weeks is required to determine the effect of weed species on mature growth stages such as tiller 2. In spite of the limitation of these studies, tiller 2 zoysiagrass development was significantly reduced from all levels of neighbor density (P <0.001).

Zoysiagrass grown with smooth crabgrass did not exceed 10% tiller 2 development at the lowest neighbor density of 61 PLS per experimental unit. In contrast, zoysiagrass populations grown with goosegrass at this same density were

Neighbor Species	Maximum yield loss (A)	Slope (I)	R^{2a}
	.... %		
Smooth crabgrass	84.1 ± 6.5	1.36 ± 0.5	0.92
Goosegrass	99.3 ± 4.0	2.02 ± 0.4	0.98

[a]Nonlinear model R^2 approximated using the formula: 1-SS(Residual) / SS(TotalCorrected)

Table 2. Estimated values of rectangular hyperbola model parameters with standard errors for zoysiagrass yield as a function of neighbor density.

comprised of approximately 25% tiller 2 plants. This difference in tiller 2 development may be correlated with the prevalence of tiller 1 stage plants in the smooth crabgrass trials. In particular, tiller 1 stage plants comprised moe than 90% of zoysiagrass populations in smooth crabgrass trials (61 PLS per experimental unit) in contrast to less than 60% with goosegrass as the neighbor species. Alternatively, differences in tiller 2 development may be due to the classification system used in these studies. Tiller 1 and tiller 2 are artificial groupings that represent a range of developmental stages that were meant to serve as a descriptive measure of population composition.

Zoysiagrass Dry Matter Yield

Neighbor density was highly significant (P<0.001) to zoysiagrass dry matter yield in all trials conducted. Zoysiagrass yield loss increased with weed density (Figure 3). Parameter estimates for the hyperbolic equation (Equation 3) are shown in Table 2.

Within the hyperbolic equation, parameter I represents percent yield loss per weed unit as density approaches zero. This parameter estimates the initial slope of the hyperbolic curve and thus provides a useful estimate of per unit yield loss to weeds when weed densities are low (10). The slope estimate (I) for zoysiagrass yield loss with goosegrass was much steeper than the estimate for smooth crabgrass (Table 2). The steeper slope estimate with goosegrass indicates that goosegrass interfered more with zoysiagrass development than smooth crabgrass in these studies. Overall, both weed species evaluated significantly reduced zoysiagrass yield, even at low densities. Based on estimates of yield loss per weed unit, one can conclude that seeded zoysiagrass (*Zoysia japonica*) is not competitive with these two annual weeds.

Parameter A in the rectangular hyperbola model represents the upper asymptote, thus estimates the maximum yield loss at high weed density. Zoysiagrass drymatter yield was reduced from 38 to 99% with increasing weed densities (Figure 3). Significant yield reduction at the high neighbor densities is directly related to zoysiagrass development, where percentage of tillering plants decreased with increasing weed density (Figures 1 and 2). In particular, zoysiagrass drymatter yield was reduced approximately 40% by both weed species at the lowest neighbor density (61 PLS per experimental unit). Using estimates of A to compare weed species, goosegrass has the potential to cause greater zoysiagrass yield loss (99%) than smooth crabgrass (84%).

Research Implications

Results from these studies indicate that weed species and density do not affect number of germinating seedlings, but that these factors do significantly impact maturation and drymatter yield of seeded zoysiagrass 8 weeks after seeding. When grown with high weed densities, the majority of plants comprising zoysiagrass populations did not reach the tiller stage, thus reducing stand density and overall quality. Dry matter yield data followed a similar trend and were fit using a rectangular hyperbola model to determine yield loss as a function of weed density. This model has been previously used successfully to determine yield loss in many agricultural crops (3, 5, 20, 30), but has not been applied to turfgrass science. Hyperbolic equation parameters (I and A) allow for comparison of weed species based on per unit yield loss and maximum yield loss. In these studies, zoysiagrass yield loss (per weed unit and maximum loss) was greater for goosegrass compared to smooth crabgrass (Table 3).

Environmental conditions within a field would likely alter the effects of weed species on zoysiagrass establishment (9). Based on our observations, studies should be conducted over a longer time scale (more than 8 weeks) to determine the competitive effect on mature growth stages. Future studies in turfgrass ecology may utilize this model to determine competitive effects of various weed species on turfgrass establishment under field conditions.

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