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Parameters of Plant Growth in Competition of *Imperata cylindrica* with Native Grass Species under Greenhouse Conditions

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Abstract: As an exotic invasive, Cogon grass (*Imperata cylindrica)* represents a severe and urgent threat to natural habitats, rights-of-way and agroecosystems in Florida. Despite decades of coordinated management strategies, *I. cylindrica* represents a major challenge toward the restoration of ecosystems in the Southeast. In the study presented here, parameters of plant growth in competitive suppression of *Cogon grass* were evaluated under greenhouse conditions using three grass species: Switchgrass (*Panicum virgatum*), maidencane (*Panicum hemitomon*) and muhly grass (*Muhlenbergia capillaries*). Plantlets, of all plants, were established before transplanting individually, or in all possible combinations with *Cogon grass*. Most grasses alone produced increased number of culms and dry weight than grown in combination. Combinations including other grasses reduced shoot and root biomass of *Cogon grass*. Significant reduction in mass of *Cogon grass* rhizomes in all combinations with other grasses occurred with greatest reductions occurring when in combination with *P. hemitomon* or *P. virgatum – M. capillaries*. Calculated relative yields indicated suppression of dry matter accumulation as a result of combination treatments. When results of all data collected were ranked and averaged, the greatest reductions of *Cogon grass* occurred with combinations of *Cogon grass* with all 3 of the other grasses or combination of *Cogon grass* with *P. hemitomon*. These findings should provide a wider understanding of Cogongrass invasion and help devise strategies to contain *I. cylindrica* spread and reclaim infested areas.

Key words: Competition · Invasive species · Native grasses · Relative yield · Cogon grass · Maiden cane · Muhly grass · Switch grass

INTRODUCTION

Cogon grass (*Imperata cylindrica* (L.)Beauv) is an invasive, rhizomatous, aggressive C_4 perennial grass that has become one of the most serious invasive species in Florida and other Gulf Coast States [1-3]. The persistent and aggressive rhizome remains the main mechanism for survival and spread and its resilience makes it difficult to control [3]. *Cogon grass* is a serious problem of forested lands, native habitats, rights of-way, interstate highways as well as phosphate-mined lands and constitutes an impediment to reclamation and restoration of these sites [3].

Control measures or management strategies for *Cogon grass* rely heavily on herbicides [3-7]. However, no chemical was able to provide complete control of *Cogon grass* [3]. Another consideration for chemical control is reinfestation by *Cogon grass* if the site is not repopulated by another plant species [3, 8].

Research on non-chemical control has been limited to a few studies [9-11]. Biological control can use insects, pathogens or competition of other plant species for the control of invasive species [12]. Competition by other plant species, including economically desirable ones could provide a viable alternative in restoring lands, as well as providing plant biomass that could have other uses such as forage or biofuels.

The legumes, *Mucuna pruriens* (L) DC*, Pueraria phaseoloides* (Roxb.) Benth.*, Centrosema pubescens* Benth. and *Psophocarsus palustris* Desv. have been used to prevent erosion and suppress weed growth [4]. Studies from Florida mining sites revealed that a

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combination of imazapyr and hairy indigo (*Indigofera hirsuta* L.) provided some measure of control but none of the vegetation species did very well in the second growing season [3]. Recently, it was noted that *Cogon grass* stands spread only to the edge of either hairy awn muhly grass (*Muhlenbergia capillaries* (Lam) Trin.) or a composite, satin grass *Pityopsis graminifolia (Michx.) Nutt*. [13].

Since the use of different plant species might suppress the growth of cogon grass, the inclusion of other species that are economically useful is warranted. Two additional grasses that could be of interest were switchgrass (*Panicum virgatum* L.) and maidencane (*P. hemitomon* Schult.). Switchgrass has been of interest lately for the production of cellulose that could be used for the production of ethanol biofuel [14]; while maidencane is used as a valuable pasture grass [15]. The use of native grass species such as *M. capillaries* or other economically viable grasses could be a novel approach for controlling invasive species such as cogon grass and could serve as an important tool in an integrated approach for the control of cogon grass.

Cogon grass has been shown to be more competitive with seedling *Paspalum notatum* Flugge (bahiagrass) than established *P. notatum* and mowing does not affect cogon grass survival [16]. The use of cover crops indicated that cogon grass could be suppressed over time, but that crop yields were also suppressed by the cover crops [17]. This long term approach worked but there were associated crop losses. Other studies with cover crops [9, 18] indicated that cover crops were able to suppress cogon grass and may have been more functional than hand weeding. In those studies, the cover crops were used in combination with either mechanical (mowing – [16] or chemical [17, 18] or combined chemical-mechanical methods [9, 19]. The competitiveness of other species such as maiden-cane could afford interesting levels of control, especially in non-crop areas such as natural habitats and/or forested ecosystems.

When attempting to develop a field experiment based on observations that cogon grass appeared to be inhibited by muhly grass, it becomes of interest to investigate if plant suppression can occur under ideal conditions of water and fertility and which parameters can be measured to provide adequate comparisons. Since cogon grass is highly rhizomal [20], the use of a greenhouse mix substrate would provide access to roots and rhizomes that might not be possible using the A horizon of a soil. In addition, by conducting an experiment with multiple sampling dates through destructive harvesting, it will be possible to evaluate parameters such as shoot and root biomass and use these as an indication of the suppression of cogon grass. The objective of this study was therefore to determine if amenity grass species could suppress the growth of cogon grass in a greenhouse study.

MATERIALS AND METHODS

Plant Material: Cogon grass was harvested from a natural infestation in Tallahassee, FL. Plants were dug up with adherent rhizomes and as little soil as possible. Maidencane "citrus" and switchgrass were obtained from field grown plants (USDA-NRCS, Plant Materials Center, Brooksville, FL.). Nodes with culms and roots of cogon grass, switchgrass and maidencane, were planted by trimming roots and rhizomes to no more than 1 cm in length and culms to approximately 15 cm in length. These were then placed into cells of #72 pro trays (Landmark Plastic Corporation, Akron, OH) and filled with commercial potting mix (Jungle Grow®, Piedmont Pacific, Statham, GA 30666). Muhly grass, a bunch grass, was purchased at a local garden center (Esposito Garden Center, Tallahassee, FL), the roots trimmed to 1 cm in length, divided into smaller clumps with a minimum of 20 culms and potted into 10 cm diameter pots. These pots were then filled with potting mix. All of these plants were placed under a mist system that applied mist for 5 sec every 15 min. After 7 days all plants and trays were moved to greenhouse benches and watered daily. Plants were grown for approximately 4 weeks in these smaller containers before being used in the potted study.

Competition Study: Accelerator pots (model AP-3, 10 in (25.4 cm) diameter, Nursery Supplies, Inc., www.nurserysupplies.com) were filled with a mix of 80 % bark, 10 % sand and 10 % peat, (Graco Fertilizer Co, Cairo, GA). Each species was transplanted into a pot either alone or in all possible combinations with cogon grass. Plant density was a single plant of each species. Therefore there were pots with each of the 4 grasses individually [cogon grass (C), switchgrass (S), muhly grass (M), or maidencane (A)] and pots that had cogon grass plus each of the other grasses individually (i.e. cogon grass plus switchgrass); cogon grass in combination with 2 grasses (i.e. cogon grass plus switchgrass plus muhly grass) and all 4 grasses in the same pot. Each pot was considered a replicate. At the beginning of the experiment for each year, enough

combinations were done to provide for 3 harvest dates (6, 12 and 18 wks). The experiment was repeated in time the following year. Also, there were 4 replicates per harvest date. This provided 4 pots of each grass or combination for harvest on each date. For example, 12 pots of cogon grass were made and 4 were harvested on each of the 3 harvest dates.

Treatments were arranged in a completely randomized block design in the George Connolly Greenhouse at Florida A&M University campus, Tallahassee, FL. Every two weeks during the study, the number of culms was counted for each of the species. Plants were watered every other day during the study; however, water was withheld 3 days before harvest. Plants were fertilized with 1 tablespoon of Osmocote® (19-6-12) (Scotts-Sierra Horticultural Products, Marysville, OH 43041) per pot on week 1 and every 4 weeks thereafter.

On each harvest date, the mass of plants was removed from the pot, the potting mix removed by pulling the root ball apart and shaking the dry mix out. The roots were then separated for each species. The shoots (culms plus rhizomes) and roots for each species were air dried for 10 days on the greenhouse bench. The relative yield (RY) [21] was calculated by taking the dry weight of shoots or roots for each individual species in each combination treatment and dividing by the average value for the shoots, or roots from the pots, which did not have competition (monoculture). These values were then pooled for either shoots or roots for the 2 years of the study.

Statistical Analysis: The number of culms per plant species per treatment was regressed against the time of the data collection for each of the two years. A single line was calculated for each plant species for within each treatment, by using all of the data collected every 2 weeks during the experiment. For example, with *Cogon grass* grown in monoculture, the first data collection would have all 4 replications of each harvest date (n=12) and this was repeated for the next 2 data collections. On the 4th data collection, the 6-week pots had been harvested so now n was reduced by 4. As the slopes of the data sets of years 1 and 2 were not significantly different they were combined and regression lines calculated (n=132) for each grass for each combination. Once the slopes for number of culms was calculated, the slopes of the calculated lines were then compared [21]. This allowed comparison of the rate of increase in the number of culms per day, within each plant species. The mean dry weights of shoots and roots and the mean number of rhizomes for each plant species within and among harvest dates were compared using LSR (least significant range), after verifying significance (α=0.05) using analysis of variance.

RESULTS

The number of culms formed by the various grasses varied over the time of the study as demonstrated by the slopes of the regression lines used to describe the data (Table 1). The goodness of fit is described by the R^2 value. At α=0.05 and n=132 an R^2 value of above 0.030 would indicate a "good fit" for the data [22]. Slopes provide a calculation of the rate of increase in the number of culms formed on a unit (day) basis throughout the term of the experiment. For example, a slope of 0.453 indicates that approximately 0.453 new culms were formed per day over the 126 days (18 weeks) of the study. This would provide a total of approximately 126x0.453 = 57 culms at the end of the sample period. By comparing slopes, an indication in the production of new culms can be obtained. Most grasses alone produced greater slopes of increase of culms than treatments that included combinations of grasses. This becomes of interest as the reduced slope indicates a reduced production of new culms, which would indicate a slower rate of expansion of the plant.

The general tendencies of dry matter production were similar for both years. In general, the values for the second year were significantly greater than the values for the first year, therefore the data could not be pooled, so for brevity, only the data from the second year will be presented. The dry weights of shoots varied more at the end of the experiment, than at the beginning (Table 2). With few exceptions, the individual plant species produced greater amounts of dry weight than the same plant in combination with other species (Tables 2). While the shoot dry weight for cogon grass, switchgrass and maidencane at the end of the study was often 10 to 20 times the dry weight at the first harvest date, muhly grass dry weights did little more than double during the study (Tables 2). The treatments with maidencane in the year 2 study, significantly reduced the production of shoot biomass of cogon grass by the 18th week, while the treatments with only switchgrass or muhly grass did not (Table 2). With respect to root production, there was no significant difference between the data from year 1 and year 2 for cogon grass and maidencane while switchgrass and muhly grass produced significantly greater root dry weights in year 2. Again, since tendencies were similar for each of the two years, the data from year 2 is presented.

Table 1: Slopes of regression lines of the number of culms formed by *Imperata cylindrica* (C); *Switchgrass* (S); *Maidencane* (A); and *Muhly grass* (M) plants. The numbers of culms were counted every 2 weeks during the study and the data for both years were pooled (n=132). Slopes, within plant species, followed by similar letters are not significantly different at p =0.01

	Cogon grass			*Switchgrass*			*Maidencane*			*Muhly grass*		
	Slope		R^2	Slope		R^2	Slope		R^2	Slope		R^2
C*	0.453	a	0.743									
S				0.088	a	0.372						
A							0.162	a	0.523			
M										0.247	a	0.207
CS	0.346	b	0.764	0.044	b	0.326						
CA	0.318	bcd	0.530				0.107	b	0.383			
CM	0.291	cd	0.622							0.141	a	0.179
CSA	0.238	d	0.462	0.041	b	0.213	0.081	c	0.644			
CSM	0.172	e	0.408	0.034	b	0.217				0.203	a	0.151
CMA	0.220	e	0.603				0.089	bc	0.487	0.145	a	0.088
CSMA	0.279	cd	0.692	0.036	b	0.036	0.074	c	0.533	0.179	a	0.175

*C = *Cogon grass*; S = *Switchgrass*; A = *Maidencane*; M = *Muhly grass*. The presence of more than one letter indicates the combination of plant species present in each treatment. The R^2 value gives an indication of goodness of fit. At á=0.05 and n=132 an R^2 value of above 0.030 would indicate a "good fit" for the data [22]

Table 2: Dry weight (g) of shoots (culms plus rhizomes) of *Cogon grass*; *Switchgrass*; *Maidencane*; and *Muhly grass*. Values are the average (± s.e.) of 4 replicates that were harvested at 6, 12 and 18 weeks of year 2 (2007) of the study. Means within each grass species followed by the same lower case letter in rows, or upper case letter in columns are not significantly different at α=0.05 by the LSR test

	Cogon grass									*Switchgrass*								
Treatment	6 wk			12 wks			18 wks			6 wks			12 wks			18 wks		
C	4.80±0.45	A	c	59.81±6.48	A	b	74.12±8.17	A	a									
S										9.05±2.42	A	c	36.40±11.61	A	b	61.17±9.97	A	a
A																		
M																		
CS	4.95±0.72	A	b	44.65±4.58	B	a	49.87±2.40	B	a	5.68±1.48	A	c	15.95±2.61	BC	b	36.05±7.57	B	a
CA	5.39±1.30	A	b	45.02±10.69	B	a	54.09±11.64	B	a									
CM	3.60±1.15	A	b	34.54±10.84	BC	a	41.42±13.77	C	a									
CSA	3.06±0.63	A	b	45.87±6.21	B	a	41.35±10.50	C	a	5.56±0.53	A	c	18.33±2.79	B	b	29.66±9.44	B	a
CSM	3.68±1.27	A	b	30.64±9.56	C	a	24.44±5.33	E	a	5.02±0.98	A	c	18.45±4.36	B	b	30.49±3.17	B	a
CAM	2.91±0.92	A	b	30.83±4.40	C	a	32.56±12.14	DE	a									
CSAM	3.84±0.68	A	c	27.64±8.47	C	b	40.56±9.65	CD	a	5.81±1.50	A	b	7.99±0.65	C	b	25.97±9.27	B	a
	Maidencane									*Muhly grass*								
	6 wks			12 wks			18 wks			6ks			12 wks			18 wks		
	2.17±0.63	A	c	13.81±6.42	A	b	28.69±5.28	A	a									
										13.82±1.52	AB	c	19.61±6.02	A	b	31.41±4.03	A	a
	3.42±1.80	A	c	13.26±6.01	A	b	19.25±1.67	B	a									
										11.21±1.39	B	b	8.59±3.50	B	b	26.25±0.82	B	a
	2.36±0.74	A	c	8.92±2.77	A	b	12.90±3.38	D	a									
										10.53±1.98	B	c	18.28±4.33	A	b	27.55±3.41	AB	a
	2.73±0.42	A	c	9.24±2.42	A	b	15.91±1.75	C	a	16.69±1.61	A	b	16.63±4.38	A	b	21.90±4.00	C	a
	3.20±1.18	A	b	11.26±1.49	A	a	10.16±0.87	D	a	12.68±1.03	AB	c	18.57±2.52	A	b	29.03±3.70	AB	a

Table 3: Dry weight (g) of roots of *Cogon grass*; *Switchgrass*; *Maidencane*; and *Muhly grass*. Values are the average (± s.e.) of 4 replicates that were harvested at 6, 12 and 18 weeks of year 2 (2007) of the study. Means within each grass species followed by the same lower case letter in rows, or upper case letter in columns are not significantly different at α=0.05 by the LSR test

	Cogon grass									*Switchgrass*								
Treatment	6 wk			12 wks			18 wks			6 wks			12 wks			18 wks		
C	0.88±0.39	A	c	5.36±3.11	A	b	13.72±5.11	A	a									
S										2.29±1.36	A	c	11.45±6.28	B	b	31.12±13.75	A	a
A																		
M																		
CS	0.85±0.27	A	b	2.33±1.20	CD	a	4.89±0.82	D	a	1.71±0.68	A	c	7.11±2.75	C	b	24.08±9.50	B	c
CA	0.77±0.14	A	c	3.89±1.93	B	b	5.56±1.17	B	a									
CM	0.44±0.32	A	b	4.88±6.94	A	b	3.87±2.58	C	a									
CSA	0.45±0.28	A	c	3.19±0.95	BC	b	4.19±2.37	C	a	1.48±0.73	A	c	8.60±3.29	C	b	17.95±11.70	D	a
CSM	0.35±0.19	A	c	5.54±4.50	A	a	1.35±0.59	E	b	1.23±0.16	A	c	6.30±3.44	D	b	16.29±6.62	E	a
CAM	0.24±0.10	A	b	2.41±1.04	CD	a	2.95±3.32	D	a									
CSAM	0.28±0.19	A	c	1.90±1.18	D	b	3.96±1.32	C	a	1.72±0.78	A	c	13.19±11.15	A	b	21.14±15.23	C	a
	Maidencane									*Muhly grass*								
	6 wks			12 wks			18 wks			6ks			12 wks			18 wks		
	0.97±0.27	A	c	4.85±4.96	A	b	12.78±4.84	A	a									
										2.78±0.76	A	b	2.68±1.16	B	b	4.12±1.33	A	a
	1.29±0.91	A	c	4.65±4.59	A	b	12.92±1.36	A	a									
										2.11±1.34	A	b	1.38±0.76	C	b	3.88±1.64	A	a
	0.74±0.28	A	b	2.71±0.48	B	a	3.92±2.03	D	a									
										1.81±0.81	A	b	4.04±1.43	A	a	3.54±1.60	A	a
	1.23±0.39	A	c	3.87±4.15	AB	b	8.36±1.32	B	a	2.81±0.92	A	ab	2.05±0.71	BC	b	3.13±0.71	A	a
	0.93±0.54	A	c	3.79±2.16	AB	b	6.48±3.36	C	a	2.43±0.71	A	b	2.09±0.58	BC	b	4.10±1.89	A	a

*C = *Cogon grass*; S = *Switchgrass*; A = *Maidencane*; M = *Muhly grass*. The presence of more than one letter indicates the combination of plant species present in each treatment

Cogon grass roots were thin and fibrous; switchgrass roots were 1 mm thick, stout and bunched; maidencane roots were 1 mm thick and flexible and muhly grass roots were thin and wiry. Root dry weight provided results similar to that of shoots (Tables 3). Cogon grass root mass was significantly reduced in all combinations with the other grasses by week 12 of both studies (Table 3). All of the grasses produced significant increases in root mass by the end of each study, but the mass of roots produced by switchgrass far exceeded that of the other grasses (Table 3).

DISCUSSION

Rhizomes are defined as underground stems and are not absorptive in nature [23]. The rhizomatous spread of the plant will permit it to explore a greater volume of soil and at the same time, permit the production of new shoots. Another interesting point is that the absorptive root weight was only about 10% of the total plant weight at harvest. This plant therefore is highly efficient at mineral and water absorption.Water use efficiency would enable cogon grass to survive and be productive where others may not, especially under stress conditions such as disturbed habitats.

Grasses are either of a bunch type in which an increase in number of culms causes only minor spreading of the plant, or rhizomatous in which the plant spreads by rhizomes (underground) or stolons (above ground) causing a vigorous spread of the plant [24]. Both switchgrass and muhlygrass are bunchgrasses [25] and most of the culms produced were within 2 cm of the original plants. On the other hand, both cogon grass and maidencane are rhizomatous [25] and they both spread throughout the pot.

Relative yield [8] is a concept that calculates the amount of growth of a plant species when in combination with other plant species, relative to the amount of growth

Table 4: Relative yield of shoots (culms plus rhizomes) of *Cogon grass*; *Switchgrass*; *Maidencane*; and *Muhly grass*. Values are calculated by taking the yield of each replicate of the plant species in the pots for each treatment and dividing by the average yield of the original plant species in the pots with that species alone. Calculations were made for each harvest date. Means (±s.e.) of the harvest dates (6, 12, 18 weeks) have data pooled from the two years. Values above 1 indicate an increase in yield, while values below 1 indicate a decrease in yield

	Cogon grass			*Switchgrass*			*Maidencane*			*Muhly grass*		
Treatment	6 wk	12 wks	18 wks	6 wk	12 wks	18 wks	6 wk	12 wks	18 wks	6 wk	12 wks	18 wks
CS	1.02±0.24	0.58±0.17	0.78±0.57	0.65±0.31	0.46±0.14	0.60±0.23						
CA	0.99±0.39	0.54±0.29	0.69±0.29				1.24±1.15	1.04±0.75	0.74±0.36			
CM	0.77±0.33	0.71±0.34	0.65±0.38							0.89±0.39	0.52±0.35	0.84±0.21
CSA	0.82±0.38	0.64±0.18	0.49±0.23	0.94±0.54	0.38±0.19	0.55±0.25	0.94±0.52	0.76±0.37	0.73±0.44			
CSM	0.90±0.57	0.80±0.18	0.44±0.28	1.17±0.69	0.42±0.27	0.55±0.19				0.81±0.21	0.78±0.35	0.90±0.33
CAM	0.89±0.48	0.55±0.28	0.56±0.35				1.37±0.67	0.85±0.58	0.83±0.42	1.16±0.3	0.77±0.37	0.73±0.20
CSAM	0.89±0.33	0.54±0.34	0.51±0.16	0.78±0.38	0.25±0.11	0.42±0.22	1.47±0.9	0.86±0.27	0.57±0.33	0.86±0.14	0.86±0.33	0.78±0.27

*C = *Cogon grass*; S = *Switchgrass*; A = *Maidencane*; M = *Muhly grass*. The presence of more than one letter indicates the combination of plant species present in each treatment

Table 5: Relative yield of roots of *Cogon grass*; *Switchgrass*; *Maidencane*; and *Muhly grass*. Values are calculated by taking the yield of each replicate of the plant species in the pots for each treatment and dividing by the average yield of the original plant species in the pots with that species alone. Means (±s.e.) of the harvest dates (6, 12, 18 weeks) have data pooled from the two years. Values above 1 indicate an increase in yield, while values below 1 indicate a decrease in yield

	Cogon grass			*Switchgrass*			*Maidencane*			*Muhly grass*		
Treatment	6 wk	12 wks	18 wks	6 wk	12 wks	18 wks	6 wk	12 wks	18 wks	6 wk	12 wks	18 wks
CS	0.94±0.31	0.51±0.33	0.34±0.09	0.81±0.35	0.72±0.49	0.73±0.27						
CA	0.75±0.32	0.63±0.32	0.38±0.15				0.83±0.82	1.28±1.11	0.95±0.45			
CM	0.77±0.43	0.66±0.89	0.25±0.14							1.25±1.12	0.49±0.26	0.86±0.39
CSA	0.42±0.23	0.54±0.20	0.27±0.15	0.95±0.68	0.50±0.34	0.64±0.33	0.50±0.35	0.68±0.35	0.64±0.56			
CSM	0.74±0.64	0.82±0.69	0.22±0.21	0.88±0.44	0.42±0.28	0.64±0.29				0.79±0.29	0.94±0.71	1.20±1.52
CAM	0.37±0.15	0.45±0.37	0.29±0.20				0.90±0.54	0.93±0.69	1.03±0.72	1.34±0.45	0.57±0.36	0.54±0.28
CSAM	0.65±0.64	0.32±0.18	0.25±0.09	1.06±0.82	0.75±0.78	0.58±0.35	0.85±0.47	1.02±0.45	0.63±0.27	1.18±0.72	0.59±0.28	0.70±0.45

*C = *Cogon grass*; S = *Switchgrass*; A = *Maidencane*; M = *Muhly grass*. The presence of more than one letter indicates the combination of plant species present in each treatment

that the plant would have had if it had been grown in monoculture without the pressure of the accompanying plant species. Relative yield should give an indication of the competitive effects of the combination of plant species. A relative yield value of less than 1 indicates suppression of growth, with numbers closer to zero indicating greater suppression. Values above 1 would then indicate stimulation of growth.

Calculated relative yield of shoots (culms+rhizomes) indicated that there was suppression of growth with the various treatments (Table 4, 5). With shoot weight relative yield, all cogon grass treatments provided at least 40% of the growth that were found in the control treatments (Table 4). For the most part, switchgrass was less competitive with most relative yields in combination below 50%. Relative yields of muhlygrass were not as affected, but muhlygrass did not produce much dry matter during the study. In all cases, there was less suppression in the first harvest date compared to the later harvest date. There was no significant difference between year 1 and 2 with respect to relative yield.

Relative yield for cogon grass roots gave reductions in all combinations (Table 5) with most treatments having about 30% of the root mass of the cogon grass alone. Switchgrass gave similar but lower reductions in root relative yield (Table 5). Surprisingly, maiden-cane in combinations with other grasses produced root relative yields that were similar to those of maiden-cane alone (Table 5).

Since this study looked at the competition with cogon grass and other amenity grasses, one possible way to visualize which overall combination of plants might be

considered best for reduction of cogon grass growth would be to rank the respective results for each data set (such as tiller increase or dry weight) and then take the mean for the rankings. Upon doing this, the combination of all 4 grasses gave lowest amounts of cogon grass biomass, followed by CSM (cogon grass-switchgrass - muhlygrass) and CA (cogon grass-maidencane). The simplicity of single species competition and its effect on Cogon grass in the field needs to be investigated.

Another aspect that is of interest is that while there were significant differences in the production of shoot dry matter between the two years, there was no significant difference in root dry weight of cogon grass and maidencane. At the same time, there was no significant difference in the number of culms produced, or in the relative yield. This would indicate that shoot dry matter production of cogon grass is not dependent upon root dry matter production, indicating the competitiveness of this species.

While the current study used plants of similar age, conditions of similar aged plants could be achieved in the field by plowing, the application of a non-selective herbicide, beginning the trial at the start of the growing season, or by mowing. Any of these conditions would check the growth of cogon grass and equal the competitive arena for the plant
being studied.

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