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Yellow nutsedge (*Cyperus esculentus*) interference in simulated sweetpotato plant beds

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Abstract

Greenhouse experiments were conducted in 2016 at Pontotoc and Verona, MS. On March 3 (Pontotoc) and March 7 (Verona), landscape fabric was placed in the bottom of polyethylene lugs, each 0.22 m^2, then approximately 5 cm of a 1:1 (v/v) blend of soilless potting media and masonry sand was added. 'Beauregard' sweetpotato [*Ipomoea batatas* (L). Lam.] storage roots weighing between 85 and 227 g, and several with emerging sprouts ≤1 cm, were placed longitudinally in a single layer on the substrate, then covered with an additional 3 cm of the substrate. Sprouted yellow nutsedge (*Cyperus esculentus* L.) tubers were transplanted equidistantly into sweetpotato-containing lugs at six densities: 0, 18, 36, 73, 109, and 145 m^{-2}. Trials were terminated 55 and 60 d after planting at Pontotoc and Verona, respectively. Predicted total sweetpotato stem cuttings (slips) decreased linearly from 399 to 312 m^{-2} as *C. esculentus* density increased from 0 to 145 m^{-2}. Predicted total slip dry weight at a *C. esculentus* density of 145 m^{-2} was reduced 21% compared with 0 m^{-2}. Predicted rotten sweetpotato storage roots increased from 2.6 to 11.3 m^{-2} as *C. esculentus* density increased from 0 to 145 m^{-2}. In response to increasing *C. esculentus* density, sweetpotato seed roots exhibited increased proximal-end dominance.

Introduction

By hectarage, Mississippi is the second largest sweetpotato [*Ipomoea batatas* (L.) Lam.]-producing state in the United States. In 2017, producers planted an estimated 12,140 ha with a direct farm value in excess of $114 million (USDA-NASS 2018). The predominant cultivar grown in the state is 'Beauregard' (Meyers 2019), an orange-fleshed, rose-skinned tablestock cultivar released in 1987 by the Louisiana State University Experiment Station (Rolston et al. 1987). In the southeastern United States, sweetpotato production occurs in two distinct phases commonly referred to as plant beds and production fields. The starting material in sweetpotato production fields is a vegetative stem tip cutting (slip). Slips are produced by placing a portion of the previous growing season's sweetpotato storage roots onto bare ground. These "seed roots" are then covered with approximately 3 cm of soil and polyethylene mulch. Approximately 4 wk later, seed root sprouts push through the soil surface, and the mulch is removed. Another 4 to 6 wk are required before the developing slips reach the desired size (25 to 35 cm) and uniformity required by commercial sweetpotato producers. Slips are cut 2.5 cm above the soil surface, packed into crates, and transported to production fields, where they are transplanted into ridged rows for the production of sweetpotato storage roots.

Weeds are prevalent in sweetpotato plant beds. However, there have been relatively few studies conducted to investigate the impact weeds have on sweetpotato slip production and quality. When clear polyethylene mulch was used, common lambsquarters (*Chenopodium album* L.) and *C. album* plus goosegrass [*Eleusine indica* (L.) Gaertn.] reduced 'Jewel' sweetpotato slip number 32% and 47%, respectively, and slip dry weight 45% and 55%, respectively, compared with a weed-free control (Monks et al. 1996). Regardless of polyethylene mulch type, Beauregard sweetpotato grown in competition with *C. album*, *E. indica*, and *C. album* plus *E. indica* resulted in 14%, 16%, and 25% reduction in slip weight, respectively, but had no effect on slip number (Monks et al. 1996). Other sweetpotato plant bed studies have focused on weed management with little investigation into weed–crop interactions (Monks et al. 1992; Smith et al. 2019).

Yellow nutsedge (*Cyperus esculentus* L.) is one of the most common and troublesome weeds in agricultural crop production systems in the southern United States (Webster and Nichols 2012), including sweetpotato (Webster 2014). *Cyperus esculentus* is a colony-forming monocotyledonous perennial weed that spreads via underground rhizomes and is propagated primarily by starchy tubers (Bryson and DeFelice 2009). In sweetpotato production fields, Meyers and Shankle (2015) reported that *C. esculentus* densities of 5 to 90 shoots m^{-2} reduced marketable sweetpotato yield 18% to 80% and 6% to 67% for two different years, respectively. In Mississippi, *C. esculentus* is equally abundant in sweetpotato plant beds, but its impact on sweetpotato slip yield and quality has not been documented.

A greater understanding of if and how weeds reduce sweetpotato slip yield and quality is needed to quantify this weed–crop interaction and justify additional research into weed management in sweetpotato plant beds. Without a greater understanding of weed–crop interactions in this system, it is not practical to make recommendations for if and when weeds in general, and *C. esculentus* specifically, need to be managed. The objectives of this study were to determine the influence of *C. esculentus* density on sweetpotato slip production and quality and to determine the influence of *C. esculentus* density on intraspecific competition and propagule production in simulated plant production beds.

Materials and Methods

Greenhouse experiments were initiated on March 3, 2016, at the Pontotoc Ridge-Flatwoods Branch Experiment Station, Pontotoc, MS (34.138°N, 89.006°W), and on March 7, 2016, at the North Mississippi Research and Extension Center, Verona, MS (34.164°N, 88.722°W). Landscape fabric was placed in the bottom of polyethylene harvest lugs (Orchard Valley Supply, Sodus, NY 14551), each 0.22 m^2, then approximately 5 cm of a 1:1 (v/v) blend of soilless potting media (Metro-Mix® 360, Sun Gro Horticulture, Agawam, MA 01001) and masonry sand was added. The resultant substrate had an organic matter content of 1.9% and pH 6.2. Twenty Beauregard sweetpotato storage roots weighing between 85 and 227 g, and several with emerging sprouts ≤1 cm, were placed longitudinally in a single layer on the substrate and then covered with an additional 3 cm of the substrate. At the same time, but in separate lugs, *C. esculentus* tubers (Cyprus Knee Chufa, Santee, SC 29142) were presprouted in a manner similar to Motis and Locascio (2004). *Cyperus esculentus* tubers were planted 2.5-cm deep into lugs containing the same potting media/sand blend and irrigated to saturate the substrate. Four days later, once *C. esculentus* tubers had sprouted, they were transplanted equidistantly into sweetpotato-containing lugs at the desired treatment densities.

Treatments consisted of six *C. esculentus* densities: 0, 4, 8, 16, 24, and 32 lug^{-1}, hereafter referred to by the equivalent densities of 0, 18, 36, 73, 109, and 145 m^{-2}. The experimental design was a randomized complete block with four replications at both locations. From initiation through 1 wk before termination of the trial, when sweetpotato plants reached ≥30 cm tall, they were trimmed with a hedge trimmer to 25 cm to simulate the commercial production practice of "topping" plant beds to promote thicker stems and greater slip uniformity. Trials were terminated 55 and 60 d after planting at Pontotoc and Verona, respectively. At crop termination, all slips were topped at 35 cm above the substrate surface. The entire contents of each lug were removed by lifting the landscape fabric. *Cyperus esculentus* shoots were counted, then

Figure 1. From left to right, sweetpotato slips separated into those ≥25 to 35 cm, ≥15 to <25 cm, and ≥10 to <15 cm at Pontotoc, MS, in 2016.

all vegetation in each lug was hand cut 2.5 cm above the media surface and separated into *C. esculentus* and sweetpotato components. Fresh weight of *C. esculentus* shoots was recorded. In a modified version of the grading system used by Barkley et al. (2017), sweetpotato slips were graded into those <10 cm (culls), ≥10 to <15 cm, ≥15 cm to <25 cm, and ≥25 cm to 35 cm by measuring the length from the proximal cut end to the shoot apical meristem (Figure 1). Fresh weight for all slip grades was recorded, and the number of slips in three largest grades were counted. With a subsample of 10 slips ≥15 cm to <25 cm and 10 slips ≥25 cm to 35 cm lug^{-1}, node number was counted and stem diameter at each slip's midpoint was measured using a digital caliper. All *C. esculentus* and sweetpotato shoot tissues were oven-dried at 70 C for 72 h, then the dry weight was recorded.

Sweetpotato storage roots and *C. esculentus* tubers were separated from the substrate by hand with the aid of a gentle stream of water. The number of rotten sweetpotato seed roots was recorded. The proximal-end dominance of sound roots was rated on a scale of 0 to 3, where 0 = no sprouts produced; 1 = sprouting at the proximal one-third only; 2 = sprouting at the proximal one-third and middle one-third of the root; and 3 = sprouting at the proximal one-third, middle one-third, and distal one-third of the root. *Cyperus esculentus* tubers were separated into those <1.3 cm and ≥ 1.3 cm and counted. Total *C. esculentus* tubers were calculated as the aggregate of both tuber sizes.

Data were subjected to ANOVA using SAS PROC GLM (SAS 9.4, SAS Institute, Cary, NC 27513) with the fixed effect of *C. esculentus* density and random effects of location and replication within location to test for location by *C. esculentus* density interaction for all data. When no interaction existed, mean data from both locations were subjected to regression analysis using JMP (JMP Pro v. 14, SAS Institute) using the nonlinear curve-fitting function to compare potential polynomial, exponential, and logarithmic models. In order to be a good fit, each parameter estimate of the model had to be significant ($P \leq 0.05$), and the model had to be biologically meaningful. With few exceptions, data were fit to the following models:

Linear (Equation 1):

$$Y = A + BX \qquad [1]$$

where Y is the predicted value, A is the y-intercept, B is the slope of the line, and X is *C. esculentus* density per square meter.

Two-parameter exponential (Equation 2):

$$Y = A[\exp(BX)] \qquad [2]$$

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Table 1. Observed and predicted sweetpotato slip and *Cyperus esculentus* shoot dry weight response to *C. esculentus* density pooled across Pontotoc and Verona, MS, locations in 2016.

	Sweetpotato slips				*C. esculentus*
C. esculentus density	≥10 to <15 cm	≥15 to <25 cm	≥25 to 35 cm	Total	Total
m^{-2}			$g\ m^{-2}$		
0	36	182	250	469	0
18	41	168	217	427	90
36	37	172	252	461	129
73	31	143	249	422	175
109	36	171	178	386	203
145	21	133	212	366	221
Model type[a]	Linear	Linear	None	Linear	Three-parameter exponential
Parameter estimates[b]	*A* = 39.8 (3.3); *B* = −0.096 (0.040)	*A* = 177.4 (9.4); *B* = −0.252 (0.115)	—	*A* = 463.9 (11.1); *B* = −0.668 (0.137)	*A* = 221.2 (9.6); *B* = −216.799 (11.090); *C* = −0.024 (0.003)
R^2	0.59	0.54	—	0.86	0.99

[a]Equations for models: linear = Equation 1; three-parameter exponential = Equation 3.
[b]SEs given in parentheses.

where *Y* is the predicted value, *A* is the scale, *B* is the growth rate, and *X* is *C. esculentus* density per square meter.

Three-parameter exponential (Equation 3):

$$Y = A + B[\exp(CX)] \quad [3]$$

where *Y* is the predicted value, *A* is the asymptote as *C. esculentus* density approaches infinity, *B* is the scale, *C* is the growth rate, and *X* is *C. esculentus* density per square meter.

Three-parameter logistic (Equation 4):

$$Y = C/\{1 + \exp[-A(X - B)]\} \quad [4]$$

where *Y* is the predicted value, *A* is the growth rate, *B* is the inflection point, *C* is the asymptote as *C. esculentus* density approaches infinity, and *X* is *C. esculentus* density per square meter.

Results and Discussion

Due to a lack of a significant *C. esculentus* density-by-location interaction, all data were pooled across the Pontotoc and Verona locations.

Sweetpotato Response

Slips ≥10 to <15 cm, ≥15 to <25 cm, and total slips per square meter demonstrated a negative linear response to *C. esculentus* density (Figure 2); however, slips ≥25 to 35 cm did not fit a biologically meaningful regression model. As *C. esculentus* density increased from 0 to 145 m^{-2}, the predicted slip number decreased from 69 to 43 m^{-2}, 159 to 118 m^{-2}, and 399 to 312 m^{-2} for slips ≥10 to <15 cm, ≥15 to <25 cm, and total slips, respectively. Sweetpotato slip dry weight demonstrated a similar response to slip number, in that slips ≥10 to <15 cm, ≥15 to <25 cm, and total slips demonstrated a negative linear response to *C. esculentus* density, but slips ≥25 to 35 cm did not fit a biologically meaningful regression model (Table 1). Predicted total slip dry weight at a *C. esculentus* density of 145 m^{-2} was reduced by 21%, a result similar to that of Monks et al. (1996), who reported a 25% reduction in total Beauregard slip dry weight associated with interference by *C. album* plus *E. indica*. However, unlike the present study, Monks et al. (1996) did not observe any impact of weed interference on slip number.

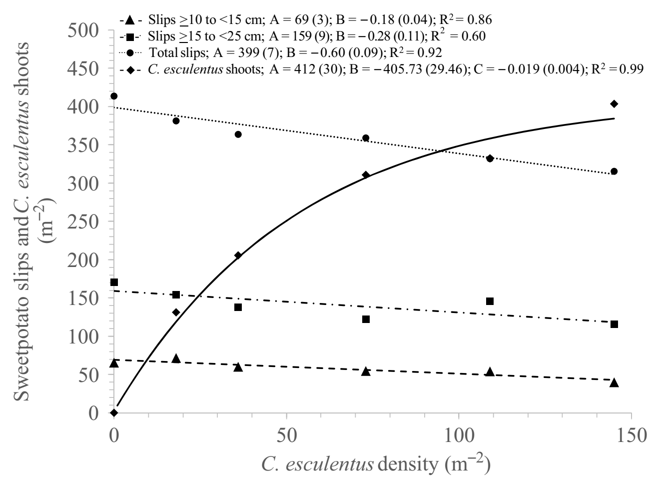

Figure 2. Effect of *Cyperus esculentus* density on sweetpotato slip yield and *C. esculentus* shoot number pooled across Pontotoc and Verona, MS, in 2016. Points represent observed mean data. Lines represent predicted values from Equations 1 (linear) and 3 (three-parameter exponential). Parameter estimates are followed by SE values in parentheses.

Proximal-end dominance rating data fit a three-parameter exponential regression model (Table 2). Predicted sprouting ratings decreased from 1.6 to 1.2 with increasing *C. esculentus* density from 0 to 145 m^{-2}, indicating restricted sprout development closer to the proximal end of the seed root. To determine the influence of proximal-end dominance on total slip production, the predicted total sweetpotato slip number was fit to a three-parameter logistic regression model with the independent variable of predicted sprouting rating (Figure 3). The strong correlation ($R^2 = 0.97$) suggests that as sprouting rating decreases from 1.61 to 1.24 due to interference by *C. esculentus*, the total number of slips produced decreases by 19% from 393 to 318 slips m^{-2}. Although others have documented the impact of genetic and environmental influences on proximal-end dominance (Basiouny 1983; Cooley and Kushman 1938; Cordner et al. 1966), to the authors' collective knowledge, this is the first reported finding that weed interference can increase proximal-end dominance and subsequently reduce sweetpotato slip production.

Stem caliper data for slips ≥15 to <25 cm and ≥25 to 35 cm and node number for slips ≥25 to 35 cm did not fit biologically

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Table 2. Observed and predicted sweetpotato sprouting rating, rotten seed roots, node number, and stem caliper in response to *Cyperus esculentus* density pooled across Pontotoc and Verona, MS, locations in 2016.

	Sweetpotato					
			Node number		Stem caliper	
C. esculentus density	Sprouting[a]	Rotten roots	≥15 to <25 cm	≥25 to 35 cm	≥15 to <25 cm	≥25 to 35 cm
m^{-2}		m^{-2}	per slip		mm	
0	1.60	3.0	4.22	3.73	3.86	4.14
18	1.49	7.0	4.38	4.10	3.85	3.99
36	1.38	3.5	4.35	4.05	4.00	4.21
73	1.24	2.7	4.05	4.18	3.84	4.23
109	1.25	7.0	3.88	3.70	3.76	4.11
145	1.26	13.1	3.98	3.78	3.71	3.93
Model type[b]	Three-parameter exponential	Two-parameter exponential	Linear	None	None	None
Parameter estimates[c]	$A = 1.23$ (0.03); $B = 0.381$ (0.039); $C = -0.028$ (0.008)	$A = 2.64$ (1.20); $B = 0.010$ (0.004)	$A = 4.34$ (0.08); $B = -0.003$ (0.001)	—	—	—
R^2	0.97	0.67	0.70	—	—	—

[a]0 = no sprouts produced; 1 = sprouting at the proximal one-third only; 2 = sprouting at the proximal one-third and middle one-third of the root; and 3 = sprouting at the proximal one-third, middle one-third, and distal one-third of the root.
[b]Equations for models: linear = Equation 1; two-parameter exponential = Equation 2; three-parameter exponential = Equation 3.
[c]SEs given in parentheses.

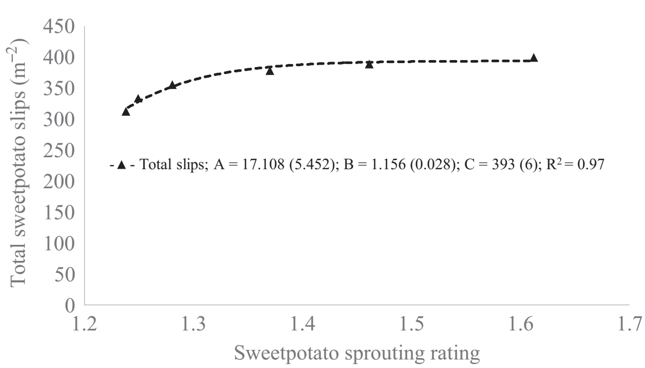

Figure 3. Effect of sweetpotato sprouting rating on total sweetpotato slip yield pooled across Pontotoc and Verona, MS, in 2016. Points represent predicted mean data. Lines represent predicted values from Equation 4 (three-parameter logistic model). Parameter estimates are followed by SE values in parentheses. Sweetpotato sprouting rating:0 = no sprouts produced; 1 = sprouting at the proximal one-third only; 2 = sprouting at the proximal one-third and middle one-third of the root; and 3 = sprouting at the proximal one-third, middle one-third, and distal one-third of the root.

meaningful regression models (Table 2). However, node number for slips ≥15 to <25 cm demonstrated a negative linear response to *C. esculentus* density. Predicted node number for slips of this grade decreased from 4.3 to 3.9 per slip as *C. esculentus* densities increased from 0 to 145 m^{-2}. Although a reduction of 0.4 nodes per slip may not seem agronomically meaningful, at an average planting population of 32,291 slips ha^{-1} and 37.8% of total slips ≥15 to <25 cm, this equates to a reduction in 4,882 total nodes ha^{-1}. Adventitious roots predominantly form at buried nodes, although some form from callus tissue at the cut end of the slip. Adventitious root number and total adventitious root length differ by node location. Ma et al. (2015) reported that in 'Georgia Jet' sweetpotato, nodes 3 and 4 from the shoot tip averaged 0.6 adventitious roots per node, whereas nodes 5 through 8 and 9 through 13 averaged 6.5 and 10.7 roots per node, respectively. Due to differences in node counting methodology, nodes 3, 4, 5, 6, and 7 referenced by Ma et al. (2015) correspond to nodes 1, 2, 3, 4, and 5 in the present study. If Georgia Jet and Beauregard are comparable in adventitious root production, based on results for Georgia Jet data from the present study suggest an average potential loss of 2.6 adventitious roots per slip ≥15 to <25 cm (0.4 nodes per slip × 6.5 roots per node) and 31,736 fewer adventitious roots ha^{-1}. Sweetpotato yield is a function of plants per hectare, storage roots per plant, and time allowed for root enlargement. Reducing the number of nodes per slip reduces the potential number of buried nodes and the potential number of storage roots per plant, thereby reducing potential yield.

Rotten storage roots per square meter fit a two-parameter exponential regression model. Predicted rotten storage roots increased from 2.6 to 11.3 m^{-2} as *C. esculentus* density increased from 0 to 145 m^{-2} (Table 2). Anecdotally, increased seed root rotting at the greatest *C. esculentus* density used in the present study is likely a function of wounding from *C. esculentus* rhizomes, shoots, and tubers penetrating into and through seed roots. Meyers and Shankle (2015) reported this phenomenon in *C. esculentus* interference trials conducted in sweetpotato production fields but did not report any incidence of rot. However, sweetpotato storage roots in production fields and plant beds are functionally different. In production fields, sweetpotato storage roots function as a carbohydrate sink with active primary and secondary growth. In plant beds, sweetpotato storage roots function as a source of carbohydrates used to produce slips. Because seed roots in plant beds are not actively growing, their ability to self-heal is greatly diminished, likely resulting in an increased incidence of decay.

Cyperus esculentus Response

Cyperus esculentus shoot number fit a three-parameter exponential regression model (Figure 2). Predicted end-of-study *C. esculentus* shoot number increased from 0 to 385 m^{-2} at the original *C. esculentus* densities of 0 to 145 m^{-2}, respectively. Relative *C. esculentus* shoot increase fit a three-parameter exponential regression model in response to original *C. esculentus* density (Figure 4). As initial *C. esculentus* density increased from 18 to 145 m^{-2}, the total number of *C. esculentus* shoots produced per plant decreased from 6.8 to 2.7, respectively. In a field trial

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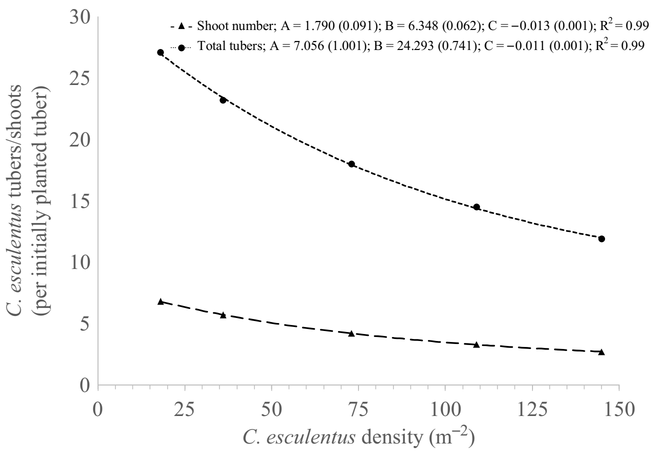

Figure 4. Effect of *Cyperus esculentus* density on relative end-of-study increase of *C. esculentus* shoot number and total tuber number per originally planted tuber pooled across Pontotoc and Verona, MS, in 2016. Points represent mean data. Lines represent predicted values from Equation 3 (three-parameter exponential model). Parameter estimates are followed by SE values in parentheses.

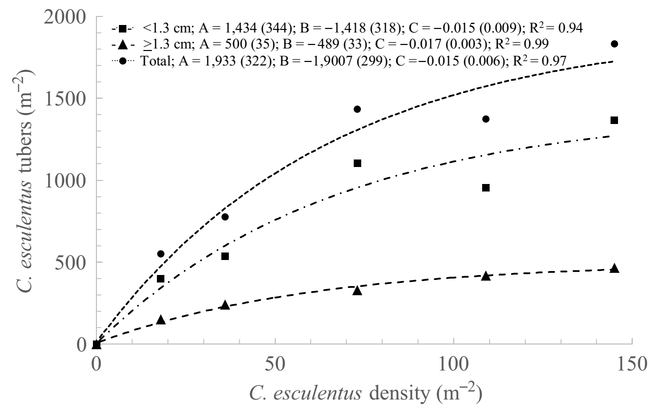

Figure 5. Effect of *Cyperus esculentus* density on *C. esculentus* tuber production pooled across Pontotoc and Verona, MS, in 2016. Points represent observed mean data. Lines represent predicted values from Equation 3 (three-parameter exponential model). Parameter estimates are followed by SE values in parentheses.

investigating the impact of *C. esculentus* interference on sweetpotato storage root production, Meyers and Shankle (2015) reported that *C. esculentus* shoot density increased by a factor of 2.3 and 7.6 from 2 wk after transplanting to harvest at two different locations. The range of relative increase in *C. esculentus* shoot number in the present study (2.7 to 6.8) falls in line with results reported by Meyers and Shankle (2015). Similar to the *C. esculentus* shoot number, predicted *C. esculentus* dry weight was fit to a three-parameter exponential regression model and increased from 0 to 214 g m^{-2} at densities of 0 to 145 m^{-2}, respectively (Table 1).

Cyperus esculentus tuber number for all three grades of tuber (<1.3 cm, ≥1.3 cm, and total) was fit to a three-parameter exponential model (Figure 5). As *C. esculentus* density increased from 0 to 145 m^{-2}, the predicted tuber number increased from 0 to 1,272 m^{-2}, 0 to 456 m^{-2}, and 0 to 1,728 m^{-2} for grades of <1.3 cm, ≥1.3 cm, and total tubers, respectively. The differences in tuber size were likely a function of each tuber's location in relation to the originally planted tuber and, consequently, the period of time allowed for growth from initiation of the tuber to the termination of the trial. Webster et al. (2008) suggested the term "first-order tubers" for those tubers attached directly to the initially planted *C. esculentus* tuber. Second and subsequently ordered tubers are those developed from daughter plants of the originally planted tuber. Relative total *C. esculentus* tuber production was fit to a three-parameter exponential regression model (Figure 4). As initial *C. esculentus* density increased from 18 to 145 m^{-2}, the total number of *C. esculentus* tubers produced per initially planted tuber decreased from 27 to 12, respectively. For comparison, Webster et al. (2008) reported that greenhouse trials consisting of single, nontreated *C. esculentus* plants in 30-cm-wide by 16-cm-tall pots produced an average of 49 tubers each after 10 wk.

In response to increasing *C. esculentus* density, sweetpotato seed roots exhibited increased proximal-end dominance, reduced total slip production, and reduced node number on slips ≥15 to <25 cm. Given the lack of effective herbicides registered to manage *C. esculentus* in sweetpotato, plant beds placed in fields with historically high populations of *C. esculentus* will require more area to generate the desired number of slips used in production fields. Not only did *C. esculentus* reduce sweetpotato slip production and quality, it was also successful at asexually propagating itself in the process. Each *C. esculentus* tuber planted at the beginning of the study generated 2.7 to 6.8 shoots and 12 to 27 tubers at the termination of the study. Intraspecific *C. esculentus* interference was also evident as relative shoot and tuber production per plant decreased as *C. esculentus* density increased. For many sweetpotato producers in the southeastern United States, once slips have been harvested, sweetpotato plant beds are disked then planted with either late-season soybean [*Glycine max* (L.) Merr.] or a cool-season vegetable crop. In either instance, the crops following sweetpotato plant beds will have to be managed for increased *C. esculentus* pressure. If no effective management strategy is available for the succeeding crop, a grower may consider managing *C. esculentus* from harvested sweetpotato plant beds using alternative methods, which could include a summer stale seedbed period or summer cover crops.

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