Optimizing Sweetpotato Seed Root Density and Size for Slip Production

Susan L. Barkley¹, Sushila Chaudhari², Jonathan R. Schultheis¹, Katherine M. Jennings¹,4, Stephen G. Bullen³, and David W. Monks¹

ADDITIONAL INDEX WORDS: cultural management, Ipomoea batatas, ‘Covington’, ‘Evangeline’, storage root size, economics, revenue, once-over harvest

SUMMARY. There is a research gap with respect to documenting the effects of sweetpotato (Ipomoea batatas) seed root density and size on transplant yield and quality. Field studies were conducted in 2012 and 2014 to determine the effect of sweetpotato seed root (canner size) density [12, 24, 37, 49, 61, 73, and 85 bushels (bu (50 lb)) per 1000 ft²] on ‘Covington’ and ‘Evangeline’ slip production in propagation beds. Another field study was conducted in 2012 and 2013; treatments included canner, no. 1, and jumbo-size ‘Covington’ roots at 49 bu/1000 ft², to determine the effect of seed root size on slip production. As seed root density increased in the propagation bed, transplant production increased with no change in slip quality as measured by node counts and slip length except for stem diameter. In 2012, the best marketable slip yield was obtained at root densities of 73 and 85 bu/1000 ft². In 2014, marketable slip production of ‘Evangeline’ increased as seed root density increased at a greater rate than ‘Covington’. In 2014, the best seed root density for marketable slip production was 49 to 85 bu/1000 ft² for ‘Covington’ and 85 bu/1000 ft² for ‘Evangeline’. In 2012, potential slip revenues increased with an increase in seed root density up to 73 bu/1000 ft². In 2014, revenue trend was similar for ‘Covington’ as 2012; however, for ‘Evangeline’, revenue was greatest at 85 bu/1000 ft². Seed root size had no effect on marketable slip production when using a once-over harvest system. Results suggest growers would use a seed root density from 49 to 85 bu/1000 ft² depending on variety, and any size roots for production of optimum marketable slips. Selection of optimum seed root density also depends on grower needs; e.g., high seed root density strategy will have a higher risk due to the upfront, higher seed costs, but potentially have higher profits at harvest time. Lower seed root density strategy would be a lower risk with a lower seed cost, but also potentially have lower net revenues.

SWEETPOTATO is an important crop worldwide, valued at over $9.4 billion (Food and Agriculture Organization of the United Nations, 2012). In the United States, sweetpotato production is valued at $698 million in gross farm value (U.S. Department of Agriculture (USDA), 2015a). North Carolina ranks first in sweetpotato production in the United States with 73,000 acres planted in 2014, which accounts for more than half of the total acreage planted nationwide (USDA, 2015b). ‘Covington’ sweetpotato, released by the North Carolina Agricultural Research Service in 2005, accounts for 88% of certified seed root acreage in North Carolina, followed by ‘Beauregard’ and ‘Evangeline’ at 5% and 3%, respectively (North Carolina Crop Improvement Association, 2014; Yencho et al., 2008). ‘Evangeline’ sweetpotato was released by the Louisiana Agricultural Experiment Station in 2007 and was reported to have southern root-knot nematode (Meloidogyne incognita) resistance, yields that are comparable to ‘Beauregard’, and an excellent flavor profile (La Bonte et al., 2008). In addition to ‘Covington’, ‘Evangeline’ under North Carolina growing conditions had been minimally investigated in terms of production practices and was, therefore, considered an important component in the study.

A sweetpotato crop is established with nonrooted cuttings (slips), which are vegetatively produced in field propagation beds. North Carolina growers use a wide (24 to 73 bu/1000 ft²) range of seed root densities to produce sweetpotato slips (D. Godwin, D. Scott, and J. Jones, personal communication). However, a lack of knowledge exists on what is the optimum seed root density and size for production of sweetpotato slips. Depending on grower’s equipment, the propagation beds are elevated about 10 inches and are 86 inches wide (Wilson et al., 1977). Mainly canner size roots (1 to 1.75 inches diameter) are used as seed source for propagation beds (Smith et al., 2009). These seed roots are cured (85 °F, 85% to 90% relative humidity (RH)) for ≈1 week after harvest to heal wounds to the skin.

### Units

| To convert U.S. to SI, multiply by | U.S. unit | SI unit | To convert SI to U.S., multiply by |
|-----------------------------------|-----------|---------|----------------------------------|
| 0.4047                            | acre(s)   | ha      | 2.4711                           |
| 3.0048                            | ft        | m       | 3.2808                           |
| 0.0929                            | ft²       | m²      | 0.01                           |
| 2.54                              | inch(es)  | cm      | 0.3937                           |
| 25.4                              | inch(es)  | mm      | 0.0394                           |
| 0.4536                            | lb        | kg      | 2.046                            |
| 48.8243                           | lb/1000 ft² | kg·ha⁻¹ | 0.0205                           |
| 1.1209                            | lb/acre   | kg·ha⁻¹ | 0.8922                           |
| 28.3495                           | oz        | g       | 0.0353                           |
| (°F – 32) + 1.8                   | °F        | °C      | (°C × 1.8) + 32                  |

---

*Cornell Technology* · February 2017 27(1)
that occurs during harvest and then stored at 55 to 60 °F and 80% to 85% RH (Edmunds et al., 2008; Kemble, 2013; Steinbauer and Kushman, 1971). Before bedding, the seed roots are presprouted in storage (85 °F, 85% RH) for 20 to 28 d (Kemble, 2013). Sweetpotato seed roots are placed into the propagation beds and then covered with 2 inches of soil (Wilson et al., 1977). Clear polyethylene mulch is then placed over the beds to increase the soil temperature and facilitate sprouting. Mulch is vented after 7 d to prevent an accumulation of carbon dioxide and then removed completely once shoot emergence begins and before bed temperatures become too hot. Once slips reach optimal size (7 to 14 inches), they are cut either by hand or with mechanical cutters, and packed in boxes (1000 slips/box) to transport and plant directly into the production field (Smith et al., 2009). Many commercial growers in North Carolina adopt a once-over harvest strategy, meaning that only one cutting is obtained from slip propagation beds. However, there are some growers that cut slips multiple times, coming back when slips have regrown to optimal size. Adopting a multiple harvest slip production strategy is common in geographical locations that have longer sweetpotato-growing seasons. Australian growers can harvest seedbed cuttings at least four to five times with 4 weeks between harvests (Northern Territory Government, 2005).

At the end of the growing season, when storage roots are harvested, a portion of the roots are saved to use as seed roots for the following year. This process is repeated for a number of years, each of which is called a generation (G). However, clones can slowly decline over each generation due to the accumulation of viruses, pathogens, and mutations (Clark et al., 2002; Villordon and LaBonte, 1996). Therefore, it is recommended to use no older than G-5 (the number indicates number of years in field production) seed root stock (Bryan et al., 2003).

Research is lacking with respect to documenting the effects of sweetpotato seed root density and size on transplant yield and quality. Thus, the primary objective of this research was to identify optimal seed root density and size of ‘Covington’ and ‘Evangeline’ that maximize production and quality of slips and return on investment. This project was conducted in direct response to grower interest and with sweetpotato industry funding.

Materials and methods

Field research was conducted in 2012 and 2013 at a commercial farm in Lucama, NC [Wilson County (lat. 35.63°N, long. 78.05°W)], and in 2014, at a commercial farm in Bailey, NC [Nash County (lat. 35.87°N, long. 78.14°W)]. The soil was an Altavista fine sandy loam (fine-loamy, mixed, semi active, thermic Aquic Hapludults) in Lucama, and in Bailey, it was Norfolk, Georgeville, and Faceville soils (fine-loamy, kaolinitic, thermic Typic Kandiudults). Growers targeted pH 6 each year for all these field studies and their sweetpotato beds. In 2012 and 2013, the crop grown in the previous year was soybean (Glycine max), while in 2014, the previous crop grown was corn (Zea mays) (S. Scott and W. Glover, personal communication). All years ‘Covington’ seed root stock was G-2 and ‘Evangeline’ was G-1, which were harvested the previous fall from several seed root producers’ commercial farms in Wilson and Nash counties, cured, and stored (Edmunds et al., 2008; Kemble, 2013; Steinbauer and Kushman, 1971).

SEED ROOT DENSITY STUDY. Seed root stock was counted and weighed corresponding to assigned treatment and transported by pallets to the field. Average weight per seed root was 3.4 oz for ‘Evangeline’ and 6.3 oz for ‘Covington’ as seed root stock was primarily comprised of (1 to 1.75 inches diameter) canner roots (USDA, 2005). Seed roots were evenly placed in propagation beds by hand on 22 Mar. 2012 and 5 Apr. 2014 at the appropriate seed root density (Fig. 1). The seed root density study was conducted in a randomized complete block design with a two-way factorial (2 × 7) arrangement of sweetpotato variety (Evangeline and Covington) and seed root density (12, 24, 37, 49, 61, 73, and 85 bu/1000 ft²) with four replicates. Dichloran (Botran; Gowan Company, Yuma, AZ) fungicide was applied to bare earth before seed roots were hand placed into beds, and again on top of seed roots after placement in the bed. Propagation beds were fertilized with 6N–2.6P–14.9K granular fertilizer at 14 lb/1000 ft². The bed maintenance and pesticide handling were done in compliance with recommendation for sweetpotato grown in the southeastern United States (Kemble, 2013). Beds were irrigated using two drip lines and covered with clear polyethylene mulch after seed roots were covered with soil. The mulch was removed when sprouts reached the soil surface. As slips in propagation beds grew, they were mowed four or five times before harvesting, theoretically to maximize uniformity and the number of marketable slips for a once-over harvest.

SEED ROOT SIZE STUDY. On 22 Mar. 2012 and 4 Apr. 2013, canner, no. 1, and jumbo-size ‘Covington’ roots, which averaged 6.3, 8.3, and 23 oz, respectively, were bedded at 49 bu/1000 ft² to determine the effect of seed root size on slip production. The study was conducted in a randomized complete block design with four replicates. The 49 bu/1000 ft² seed root density rate was considered to be the average seed root density used by commercial farmers. Seed roots were graded according to the USDA and North Carolina Department of Agriculture (USDA, 2005) standard that classify roots into no. 1 (diameter of 1.75 to 3.4 inches and length of 3 to 9 inches), canner (diameter 1 to 1.75 inches), and jumbo (diameter >3.5 inches) roots.

PLOT SIZE AND DATA COLLECTED. Each plot was a 3 ft wide × 20 ft long.
null
agroclimatic conditions due to an interaction of genetic makeup and environment (Jilani et al., 2009).

Extra-long slip (>14 inches) production was not influenced by seed root density (Table 2), but there were varietal differences. ‘Evangeline’ produced more extra-long slips than ‘Covington’ (3.3 and 1.6 boxes/1000 ft², respectively). Cull and marginal slip production was influenced by the interaction of seed root density and variety. Seed root density did not have an impact on cull slip production for ‘Evangeline’; however, for ‘Covington’, production of cull slips increased with an increase in seed root density (Table 2). Marginal sized slip production increased with an increase in seed root density; however, ‘Covington’ produced more marginal size slips than ‘Evangeline’ as seed root density increased (Table 2).

In 2012, the interaction between seed root density and variety (P > 0.05) was not significant for optimal, marketable, or total slip production; therefore, data were combined from both varieties to find the influence of seed root density on optimal slip production (Fig. 3). As seed root density increased, optimal, marketable, or total slip productions increased, and mean separation analysis indicated that significantly higher slip production occurred for seed root density of 73 and 85 bu/1000 ft² compared with all other densities (Fig. 3). In 2014, the interaction between seed root density and variety was significant for optimal (P < 0.001), marketable (P < 0.001), and total (P = 0.001) slip production; therefore, data are presented by variety (Fig. 4). A linear and quadratic increase for optimal, marketable, or total slip production was observed as seed root density increased for ‘Evangeline’ and ‘Covington’, respectively. An interaction between variety and seed root density showed that optimal, marketable, or total slip production for ‘Evangeline’ increased at a faster rate than ‘Covington’ (Fig. 4). Mean separation analysis for ‘Covington’ indicated that optimal and marketable slip production from 49 to 85 bu/1000 ft² were not significantly different, suggesting that increase in seed root density from 49 to 85 bu/1000 ft² did not increase slip production (Fig. 4). Mean separation analysis for ‘Evangeline’ indicated that optimal and marketable slip production from 49 to 73 bu/1000 ft² were not significantly different; however, at these densities the slip production was lower than 85 bu/1000 ft². This suggests that for ‘Evangeline’, an increase in seed root density from 49 to 73 bu/1000 ft² did not increase slip production, but at seed root density of 85 bu/1000 ft², slip production increased significantly.

Environmental factors can also have detrimental effects on the survival and/or thriving of slips for root production. Many North Carolina

---

**Table 1. Probability > F for slip production of sweetpotato for each grade as influenced by seed root density and variety at Lucama and Bailey, NC, in 2012 and 2014, respectively.**

| Variable | Cull  | Marginal | Extra-long | Optimal | Marketable | Total | Wt/slip |
|----------|-------|----------|------------|---------|------------|-------|---------|
| Year (Y) | 0.003 | 0.001    | 0.203      | 0.006   | 0.008      | <0.001| <0.001  |
| Density (D) | <0.001 | <0.001 | 0.264 | <0.001 | <0.001 | <0.001 | <0.001 |
| Variety (V) | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.007 | <0.001 |
| D × V | 0.001 | <0.001 | 0.217 | 0.005 | 0.023 | 0.359 | <0.001 |
| Y × D | 0.001 | 0.075 | 0.811 | <0.001 | <0.001 | <0.001 | 0.064 |
| Y × V | 0.451 | 0.051 | 0.061 | <0.001 | <0.001 | 0.074 | <0.001 |
| Y × V × D | 0.886 | 0.248 | 0.725 | <0.001 | <0.001 | 0.442 | <0.001 |

**Fig. 2. The influence of sweetpotato seed root density on individual slip weight of optimal slip (7 to 14 inches) combined over both years (2012 and 2014) for ‘Covington’ and ‘Evangeline’. Different letters within a variety indicate statistically significant difference between seed root density based on Fisher’s protected least significant differences at P ≤ 0.05. ‘Covington’ slip weight: \( Y = 28.28 - 0.42X + 0.003X^2 \) \( (R^2 = 0.98) \), ‘Evangeline’ slip weight: \( Y = 17.6 - 0.28X + 0.002X^2 \) \( (R^2 = 0.96) \), 1 g = 0.0353 oz; 1 inch = 2.54 cm, one 50-lb (22.68 kg) bushel/1000 ft² = 2441.2138 kg-ha⁻¹.
sweetpotato fields are not irrigated. Slips are typically transplanted into production fields and watered simultaneously by the mechanical transplanter, but are then reliant on rainfall. Ample slip tissue above and below the soil surface enables the slip to survive the hot and sometimes dry conditions that are prevalent during North Carolina’s growing season. Irrigated slips typically show higher stand percentages vs. nonirrigated slips (Thompson, 2014). It is important to note that while marginal (5 to <7 inches) slips may survive transplanting, the best success for thriving, productive slips are found within the optimal slip size range (7 to 14 inches). A recent study found that slips between 20 and 30 cm consistently provided higher plant stands and yields for ‘Covington’ sweetpotato than 9.5-cm slips (Thompson, 2014). Limited slip tissue below the soil surface can limit root initiation due to reduced number of nodes (Thompson, 2014). Therefore, fewer nodes will likely lead to a reduction in root set and overall yields. A minimum of three nodes under the soil surface has been recommended (Granberry et al., 1986). Studies on vegetatively propagated cassava (Manihot esculenta) have also found that longer transplants result in higher yields (Ekandem, 1962; Rodriguez and Sanchez de Bustamante, 1963).

Extra-long slips have the length necessary to survive, but are sometimes more difficult to handle during transplanting. These slips are typically cut to appropriate length when packed together into boxes after harvest and are, therefore, considered marketable. The best slips are not only the appropriate length but are also straight. Extra-long slips tend to be curved, which can cause problems during transplanting. Extra laborers are then needed to handstick the curved or missed slips into the planting rows.

Using total slips as a means for selecting particular varieties for superior slip production would not be advisable. Total slip production includes unusable or cull slips. Optimal slip (7 to 14 inches) production is of utmost consideration in selecting varieties and seed root density, not only for slip production but also for subsequent storage root set in field production. However, extra-long and marginal slips have their own negative points along with benefits; therefore, both of these categories of slips are included as marketable slips. Using marketable slips as a means for selecting particular varieties for superior slip production would be advisable.

**SLIP QUALITY.** The interaction for year × density × variety was not significant for number of nodes per slip, slip diameter, and slip length; therefore, data are combined over both years. The interaction for density × variety was not significant for
number of nodes per slip ($P = 0.355$), slip diameter ($P = 0.100$), and slip length ($P = 0.264$). Number of nodes per slip was unaffected by either seed root density ($P = 0.070$) or variety ($P = 0.173$) (data not shown). Number of nodes per slip ranged from 8 to 10 nodes per slip. Differences in slip stem diameter were observed between varieties ($P < 0.001$) and seed root density ($P = 0.006$). ‘Covington’ slips were larger in diameter (4.62 mm), in contrast to ‘Evangeline’ (3.67 mm). This difference was likely due to the stocky growth habit of ‘Covington’. Larger stem diameter of slips (4.4 mm) were obtained from 12 bu/1000 ft$^2$ seed root density compared with all other densities where slip diameter ranged from 4 to 4.2 mm. Slip length was only influenced by variety ($P < 0.001$), and ‘Covington’ slips were smaller in length (9.3 inches) than ‘Evangeline’ (9.6 inches). Our hypothesis was that the highest seed root density treatments would show a decrease in slip quality due to increased competition for nutrients, water, light, and space. However, these results indicate that increased seed root density does not have measurable negative impacts on slip quality including node counts, and slip length except on slip diameter at the densities evaluated.

**Economic Assessment.** Gross revenue generated from marketable slip production increased as seed root density increased from 12 to 73 bu/1000 ft$^2$ during the year 2012 with yield data for both varieties combined (Table 3). Revenue after subtracting seed root cost ranged from $271 to $772 per 1000 ft$^2$ for seed root density treatments (Table 3). Adopting a higher (61 and 73 bu/1000 ft$^2$) seed root density could increase revenue by 17% and 36%, respectively, relative to average commercial (49 bu/1000 ft$^2$) bedding density (Table 3). However, further increase in seed root density to 85 bu/1000 ft$^2$ resulted in decreased revenue ($20/1000 ft^2$) compared with 61 and 73 bu/1000 ft$^2$ ($101$ and $275/1000 ft^2$, respectively) due mainly to higher seed cost and decrease in slip yield (Table 3).

During 2014, cost-benefit analysis of seed root densities for marketable slip production was presented by varieties due to the yield difference between both varieties (Table 4). ‘Covington’ revenue after subtracting seed root cost was $2441.2138 kg/ha$–$1$.

| Seed root density (bushels/1000 ft$^2$) | Slips (boxes/1000 ft$^2$) | Gross revenue ($/1,000 ft^2$) | Seed root cost ($/1,000 ft^2$) | Revenue after seed root cost ($/1,000 ft^2$) | Change in revenue ($/1,000 ft^2$) | Change (%) |
|----------------------------------------|---------------------------|-------------------------------|--------------------------------|-----------------------------------------------|---------------------------------|------------|
| 12                                     | 8.9                       | 355                           | 84                             | 271                                           | -226                            | -83        |
| 24                                     | 15.1                      | 602                           | 168                           | 434                                           | -63                             | -15        |
| 37                                     | 19.3                      | 772                           | 259                           | 513                                           | 16                              | 3          |
| 49                                     | 21.0                      | 840                           | 343                           | 497                                           | 0                               | 0          |
| 61                                     | 25.6                      | 1,025                         | 427                           | 598                                           | 101                             | 17         |
| 73                                     | 32.1                      | 1,283                         | 511                           | 772                                           | 275                             | 36         |
| 85                                     | 27.8                      | 1,112                         | 595                           | 517                                           | 20                              | 4          |

Table 3. Cost-benefit analysis of seed root densities for marketable slip production of sweetpotato at Lucama, NC, in 2012 (combined over varieties).

Fig. 4. The influence of seed root density on slip production. (A) Optimal (B) marketable, and (C) total of ‘Covington’ and ‘Evangeline’ sweetpotato varieties at Bailey, NC, in 2014. Different letters within a variety indicate statistically significant difference between seed root density based on Fisher’s protected least significant differences at $P \leq 0.05$. (A) Optimal ‘Covington’ slips: $Y = 0.92 + 0.36X - 0.001X^2$ ($R^2 = 0.86$), optimal ‘Evangeline’ slips: $Y = 1.23 + 0.69X$ ($R^2 = 0.93$); (B) marketable ‘Covington’ slips: $Y = 2.01 + 0.64X - 0.003X^2$ ($R^2 = 0.96$), marketable ‘Evangeline’ slips: $Y = 4.41 + 0.77X$ ($R^2 = 0.93$); (C) total ‘Covington’ slips: $Y = 0.51 + 1.18X - 0.006X^2$ ($R^2 = 0.98$), total ‘Evangeline’ slips: $Y = 7.75 + 0.93X$ ($R^2 = 0.93$); one box (1000 slips)/1000 ft$^2$ = 107.6391 boxes/ha, one 50-lb (22.68 kg) bushel/1000 ft$^2$ = 2441.2138 kg/ha$^–$1.
seed root cost ranged from $297 to $780 per 1000 ft² for the range of seed density treatments (Table 4). Comparatively, revenue after subtracting seed cost was higher for ‘Evangeline’ than ‘Covington’, and it ranged from $360 to $2401 per 1000 ft² for same range of seed density (Table 4). For ‘Covington’, change in revenue for adopting higher than standard seed density was variable, with decreased revenue at 61 bu/1000 ft², a marginal increase of 4% at 73 bu/1000 ft², and a 13% decrease at 85 bu/1000 ft². In the case of ‘Evangeline’, an increase in seed density up to 73 bu/1000 ft² resulted in decreased revenue, but a further increase in seed density to 85 bu/1000 ft² increased the revenue after subtracting seed cost by 31% (Table 4). This shows that the economic gains from changing seed density could vary with variety of sweetpotato grown.

Seeding propagation beds with higher seed root densities would have a high upfront cost and, therefore, could be considered a high-risk strategy. Seed root costs started from $84 and increased up to $595/1000 ft² for seed root densities that ranged from 12 to 85 bu/1000 ft². Environmental conditions cannot be controlled, so growers need to be cognizant of the financial risk with increased seed root costs associated with higher densities. However, the net benefit from such a strategy could increase profits greatly. Differences between varieties can also play a role in deciding seed root density strategy. Lastly, we only considered increased seed root costs in our economic assessment of changing seed root densities. Thus, our increased potential revenues with increased seed root density do not consider the savings a producer would gain in bedding on less acreage. Savings in pesticide, fertilizer, drip tape, and efficiency of labor may all enhance grower revenue at higher seeding densities (J. Jones, personal communication). One reason behind not adding these costs is that these may vary by grower operation and worker efficiency. The other is to realize that whole seed root planting on beds is a highly mechanized process and these other costs would contribute very minimally with respect to the economics of marketable slip production with increases in seed root density. Thus, our economic assessment provides a conservative value a producer might gain by increasing seed root density.

### Seed root size study

The interaction for year × seed root size was not significant for production of slips for any grades including cull, marginal, extra-long, optimal, total, and marketable; therefore, data were combined over both years. Seed root size had little to no effect on slip production. No difference between canner, no. 1, and jumbo roots were observed for cull, marginal, optimal, total, and marketable slip production (Table 5). The only significance found was that jumbo roots produced more extra-long slips than no. 1 or canner seed roots (Table 5). These results likely occurred due to the wider spacing between the jumbo roots in the propagation bed (Fig. 5). This spacing likely results in less plant competition and more space for the slips to vine out horizontally. These results suggest that using larger grades of seed roots for slip production does not increase or decrease yield for a once-over sweetpotato harvest system. In slip production systems where slips are harvested multiple times, larger sized roots may need to be considered since more energy reserves in the root may be required to produce slips over a longer period of time in places like Australia (Northern Territory Government, 2005).

### Summary

These studies evaluated slip production in sweetpotato with varying seed root size and densities. Overall, seed root size had no effect on marketable slip production when using a once-over harvest system. Treatments in the seed root density study were designed to include a broad range of densities to account for variations in reported density from the North Carolina commercial sweetpotato industry. Results obtained within the range evaluated indicate that
increasing seed root density will also increase overall slip production without a negative effect on slip quality as measured by length and nodes per slip. In 2012, the best marketable slip yield was obtained at 73 and 85 bu/1000 ft². In 2014, marketable slip production of ‘Evangeline’ increased as seed root density increased at a greater rate than ‘Covington’. In 2014, the best seed root density for marketable slip yield was 49–85 and 85 bu/1000 ft² for ‘Covington’ and ‘Evangeline’, respectively.

An even greater increase might be observed at higher seed root densities in ‘Evangeline’; however, this requires further study. Slip production would be expected to level off and drop at some point once a seed root density was reached in which more slips could not overcome the limits of resources such as space, light, and water. Research on other crop species, such as fodder radish (Raphanus sativus var. oleiferus), has shown this quadratic trend, where once the optimum point of seed density and seedling emergence was passed, increased seed density caused a decrease in initial stand and seedling emergence (Oliveira et al., 2011). Another aspect to consider is that increasing seed root density beyond what was evaluated in this study could cause seed root stacking within the beds, which would prohibit the lower seed roots from producing sprouts (J. Jones, personal communication).

Results also indicate that slip production can differ widely between varieties. Seed root density strategies can be tailored to suit grower needs; e.g., high seed root density strategy will have a higher risk due to the upfront, higher seed costs but potentially have higher payoffs at harvest time. Lower seed root density strategy would be a lower initial risk with a lower seed cost but also potentially have lower net revenues. The direct effects of seed root density on slip production, and therefore on revenue, place this production management practice as a very important consideration in the sweetpotato industry. Further research should be conducted to test other commercially grown varieties along with ‘Evangeline’ and to investigate potential yield increases with increased seed root density. Conversely, an investigation into higher seed root densities could also reveal the point where slip production would level off and possibly even decrease. Lastly, it should be noted that these results represent a once-over harvest slip production system rather than slip production systems that employ two or more harvests as is common with some growers.

**Table 5. Slip production of sweetpotato by grade as influenced by seed root sizes at Lucama, NC, in 2012 and 2013.**

| Seed root size² | Optimal (7 to 14 inches)¹ | Marginal (5 to <7 inches) | Extra-long (>14 inches) | Cull (<5 inches) | Total | Marketable² |
|----------------|--------------------------|---------------------------|------------------------|-----------------|-------|-------------|
|                | Slips (boxes/1,000 ft²)  |                           |                        |                 |       |             |
| Canner         | 15                        | 5                         | 2 b                   | 11              | 31    | 20          |
| No. 1          | 14                        | 4                         | 1 b                   | 8               | 29    | 20          |
| Jumbo          | 12                        | 3                         | 3 a                   | 7               | 24    | 17          |
| LSD            | 0.622                     | 0.139                     | 0.049                 | 0.262           | 0.498 | 0.668       |

*Means followed by a different letter within a column are significantly different according to Fisher’s protected LSD (*P* < 0.05).

**Fig. 5. Seed root size by grade of ‘Covington’ bedded at 49 bushels/1000 ft² (119,619.5 kg·ha⁻¹).** Average ‘Covington’ root weight for canner, no. 1, and jumbo size roots was 6.3, 8.3, and 23 oz, respectively; 1 oz = 28.3495 g.

**Literature cited**

Bryan, A.D., Z. Pesic-VanEsbroeck, J.R. Schultheis, K.V. Pecota, W.H. Swallow, and G.C. Yencho. 2003. Cultivar decline in sweetpotato: I. Impact of micro-propagation on yield, storage root quality, and virus incidence in ‘Beauregard’. J. Amer. Soc. Hort. Sci. 128:846–855.

Casper, B.B. and R.B. Jackson. 1997. Plant competition underground. Annu. Rev. Ecol. Syst. 28:545–570.

Clark, C.A., R.A. Valverde, S. Fuentes, L.F. Salazar, and J.W. Moyer. 2002. Research for improved management of sweetpotato pests and diseases: Cultivar decline. Acta Hortic. 583:103–112.

Edmunds, B.A., M.D. Boyette, C.A. Clark, D.M. Ferrin, T.P. Smith, and G.J. Holmes. 2008. Postharvest handling of sweetpotatoes. North Carolina Coop. Ext. Serv. AG-413-10-B.

Ekandem, M.J. 1962. Cassava in Nigeria. Part I. Federal Dept. Agr. Res. Memo 42:3–4.

Food and Agriculture Organization of the United Nations. 2012. Food and agriculture organization statistical yearbook 2012. 22 Apr. 2014. <http://www.fao.org/docrep/015/i2490e/i2490e00.htm>.

Granberry, D.M., P. Colditz, and W.J. McLaurin. 1986. Sweet potato. Georgia Ext. Bul. 677.
Jilani, M.S., M.Q. Khan, and S. Rahman. 2009. Planting densities effect on yield and yield components of onion (*Allium cepa* L.). *J. Agr. Res.* 47:397–404.

Kemble, J.M. 2013. 2013 Southeastern U.S. vegetable crop handbook. Vance Publ., Lincolnshire, IL.

La Bonte, D.R., P.W. Wilson, A.Q. Villordon, and C.A. Clark. 2008. ‘Evangeline’ sweetpotato. *HortScience* 43:258–259.

North Carolina Crop Improvement Association. 2014. Seed list 2013–2014. 22 Apr. 2014. <http://www.nccrop.com/files/2013-2014%20SEED%20LIST%20%28winter%29.pdf>.

Northern Territory Government. 2005. Sweet potato production guide for the top end. 28 Feb. 2015. <http://www.nt.gov.au/d/Content/File/p/Vegetable/IB1.pdf>.

Oliveira, A. dos S., M.L.M. de Carvalho, M.C. Nery, J.A. Oliveira, and R.M. Guimarães. 2011. Seed quality and optimal spatial arrangement of fodder radish. *Sci. Agr.* 68:417–423.

Rodriguez, N.F. and C.A. Sanchez de Bustamante. 1963. Importance of type of cutting for the production of cassava in Misiones. *Revista Investigacion Agricola* Buenos Aires 17:289–302.

Sanderson, M.A. and R.L. Reed. 2000. Switchgrass growth and development: Water, nitrogen, and plant density effects. *J. Range Mgt.* 53:221–227.

Smith, T.P., S. Stoddard, M. Shankle, and J.R. Schultheis. 2009. The sweetpotato, p. 287–323. In: G. Loebenstein and G. Thoufappilly (eds.). Sweetpotato production in the United States. Springer, Dordrecht, The Netherlands.

Steinbauer, C.E. and L.J. Kushman. 1971. Curing and storage, p. 42–46. In: C.E. Steinbauer and L.J. Kushman (eds.). Sweetpotato culture and diseases. U.S. Dept. Agr., Agr. Res. Serv., Agr. Hdbk. 388.

Thompson, W.B. 2014. Sweetpotato transplant establishment considerations for sweetpotato production in North Carolina. MS Thesis, North Carolina State Univ., Raleigh, NC.

U.S. Department of Agriculture (USDA). 2005. United States standards for grades of sweetpotatoes. 15 Nov. 2014. <http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5050330>.

U.S. Department of Agriculture (USDA). 2015a. Crop values 2014 summary. 25 Feb. 2015. <http://usda.mannlib.cornell.edu/usda/nass/CropValuSu//2010s/2015/CropValuSu-02-24-2015_correction.pdf>.

U.S. Department of Agriculture (USDA). 2015b. Crop production 2014 summary. 22 Feb. 2015. <https://www.census.gov/history/pdf/cropan15.pdf>.

Villordon, A.Q. and D.R. LaBonte. 1996. Genetic variation among sweetpotatoes propagated through nodal and adventitious sprouts. *J. Amer. Soc. Hort. Sci.* 121:170–174.

Wilson, L.G., H.M. Covington, and C.W. Averre. 1977. Sweetpotato production, handling, curing, storage, and marketing in North Carolina. Proc. Symp. Intl. Soc. Tropical Root Crops. p. 146–150.

Wilson, S.D. and D. Tilman. 1991. Components of plant competition along an experimental gradient of nitrogen availability. *Ecology* 72:1050–1065.

Yencho, G.C., B.E. Little, A.C. Thornton, V. Truong, G.J. Holmes, K.V. Pecotas, J.R. Schultheis, and Z. VanEsbroeck. 2008. ‘Covington’ sweetpotato. *HortScience* 43:1911–1914.