Evaluation of New Okra Cultivars for Bare Ground and Plasticulture Production

Eric Simonne,[1]
Bob Hochmuth,[2] Jeff Simons,[3]
Edgar Vinson, III,[4]
and Arnold Caylor[5]

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SUMMARY. **Several okra (*Abelmoschus esculentus*) cultivars are now available as alternatives to the standards 'Clemson Spineless' (open pollinated) and 'Annie Oakley II' (hybrid). Based on the results of four trials involving 20 cultivars, 'Mita', 'Spike', 'Green Best' and 'North & South' should be added to the list of recommended cultivars for Alabama and Florida. The experimental 'SOK 601' should also be included on that list, but on a for trial basis since it was evaluated only at one location. Other cultivars may perform well at specific locations. Differences among cultivars were also found for ease of harvest. 'North & South' and 'Baby Bubba' were the easiest and most difficult cultivars to harvest, respectively. The economic feasability of selecting a hybrid cultivar over an open-pollinated one and using plasticulture instead of bare ground was also examined in this study. Using hybrid seeds resulted in an average yield increase per harvest of 92 lb/acre (103 kg·ha^{-1}), which exceeded the estimated 75 lb/acre yield (84 kg·ha^{-1}) increase necessary to offset the additional cost of hybrid seeds. For reasons ranging from improved weed control, increased nutrient and water use efficiency, and double cropping, an increasing interest exists to produce okra with plasticulture, instead of bare ground as done traditionally. The average yield increase per harvest due to plasticulture over bare ground production was 196 lb/acre (220 kg·ha^{-1}). Based on this number, it would take three harvests to produce the 540 lb/acre (605 kg·ha^{-1}) yield increase necessary to offset the additional costs due to plasticulture.**

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[1]Horticultural Sciences Department, 1241 Fifield Hall, PO Box 110690, University of Florida, Gainsville, FL 32611-0690

[2]North Florida Research and Education Center–Suwannee Valley.

[3]Florida Agricultural Extension Service, Nassau county.

[4]Department of Horticulture, Auburn University.

[5]Alabama Agricultural Experiment Station.

Okra is a versatile warm-season crop produced for its immature pods in the United States, but for its leaves, seed oil and protein, gums, and fiber in other parts of the world (Lamont, 1999). For immature pod production, important attributes of okra are pod shape and color, earliness, and total marketable yield. As all okra is hand harvested, plant height and architecture, as well as the absence of spines and/or trichomes are important to facilitate harvest. While in the southeastern U.S. okra has been traditionally produced by commercial growers and gardeners on bare-ground and often without irrigation, several successful attempts to grow it on bare ground with irrigation, or with plasiculture have been reported (Khan et al., 1990, 1991; Lamont, 1999; Maynard, 1987; Simonne et al., 1998, 1999a).

Although the okra germplasm world-wide is diverse (Arulrajah and Ormrod, 1973; Inforzato and Bernardi, 1974; Joshi et al., 1974), a limited number of cultivars is readily available in the U.S. for commercial production (Simonne et al., 2000). The open-pollinated cultivars 'Clemson Spineless' and 'Clemson Spineless 80', along with the hybrid cultivar Annie Oakley II, are popular cultivars for bare ground production. Current recommendations are to use 'Annie Oakley II', 'Cajun Delight', 'Clemson Spineless 80', 'Emerald' and 'Lee' in Alabama (Sanders, 1999) and 'Annie Oakley II', 'Cajun Delight', and 'Clemson Spineless 80' in Florida (Hochmuth at al., 2000). As drip irrigation and plasticulture gain in popularity for vegetable crop production, information is needed on the performance of okra cultivars with these alternate production methods. Also, traditional okra growers who have been producing open-pollinated cultivars on bare ground wonder how economical it is to plant hybrid cultivars, and whether plasticulture will increase their profits. Thus, the objectives of this research were to 1) evaluate the field performance and plant characteristics of selected new okra cultivars grown on bare ground and with plasticulture, and update recommendations accordingly, 2) develop a harvest index for okra, and 3) use these yield data to address growers concerns about the profitability of hybrids and plasticulture for the commercial production of okra.

Materials and methods

Twenty okra cultivars were selected for their general availability, yield potential, and diversity in pod shape and color. While most okra pods are green and ridged, cultivars with white ('White Velvet') or red ('Burgundy') pods, smooth pods ('Cowhorn', 'Emerald Green', 'Louisiana Green Velvet', White Velvet'), and unconventionally shaped [thin, elongated ('Cowhorn') and short, blocky ('Big'Un')] were also evaluated (Table 1). Four okra cultivar trials were conducted at the North Alabama Horticulture Research Station (NAHS) in Cullman, Ala. on a Hartsell fine sandy soil in 1998 (Trial 1) and 1999 (Trial 2), the North Florida Research and Extension Center, Suwanee Valley (NFREC) in Live Oak, Fla. on a Lakeland fine sandy soil in 2000 (Trial 3), and on a commercial field in Suwannee County, Fla. (COMM) in 2000 on a Lakeland fine sandy soil (Trial 4). Production system was bare-ground with drip irrigation for Trials 1 and 4, and plasticulture for Trials 2 and 3.

Fertilization and cultural practices followed the recommendations of the Alabama Cooperative Extension System for Trials 1 and 2 (Sanders, 1999), and those of the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) for Trials 3 and 4 (Hochmuth et al., 2000). For Trial 1 (NAHS-98), fertilization consisted of a preplant application of 230 lb/acre (258 kg·ha^{-1}) of ammonium nitrate on 24 Apr. and one sidedress application of ammonium nitrate at a rate of 115 lb/acre (129 kg·ha^{-1}) on 29 May. This provided a total nitrogen (N) of 135 lb/acre (151 kg·ha^{-1}). Okra was direct seeded on 4 May in single rows at a

within-row spacing of 1.5 ft (0.45 m) onto 20-ft (6.2-m) long, drip-irrigated, bare-ground plots. Distance between rows was 5 ft (1.5 m), which created a population of 5,800 plants/acre (14,356 plants/ha). No insecticide, herbicide or fungicides were necessary. Okra was harvested 14 times between 5 July and 3 Aug.

In Trial 2 (NAHS-99), preplant fertilization consisted of an application of N of 80 lb/acre (90 kg·ha^{-1}) as ammonium nitrate on 19 Apr. Okra was direct seeded on 28 May onto 20-ft-long, drip-irrigated plots covered with silver plastic mulch. Distance between beds was 5 ft and within-row spacing was 1.5 ft, which created a stand of 5,800 plants/acre. Supplemental N fertilizer was injected at a weekly rate of 10 lb/acre (11 kg·ha^{-1}) between 4 June and 6 Aug. Total N application was 220 lb/acre (247 kg·ha^{-1}). Fungicides used were chlorothalonil [at 3 pt/acre (4.2 Lha^{-1})] on 15 and 28 July, and mancozeb [at 2 lb/acre (2.2 kg·ha^{-1})] on 22 July. Plots were harvested twice weekly from 12 July to 12 Aug.

In Trial 3 (NFREC-00), preplant fertilization consisted of an application of a 13N-1.7P-10.8K fertilizer at the rate of 500 lb/acre (560 kg·ha^{-1}). Okra was transplanted on 7 Apr. in double rows 1 ft (0.3 m) apart, onto 10-ft-long (3 m) plots at a within-row spacing of 1 ft. Center-to-center distance between beds was 5 ft, which created a stand of 8,700 plants/acre (21,535 plants/ha). Beginning 4 weeks after transplanting and through final harvest, additional N and potassium (K) were injected daily through the drip system. Total N and K used (applied+injected) was 175 lb/acre each (196 kg·ha^{-1}) for the whole season. No fungicides were used, but malathion was applied on 16 and 30 June to control stink bugs. Okra was harvested 3 times weekly between May and July for a total number of 21 harvests.

In Trial 4 (COMM-00), N was banded over the row at a rate of 40 lb/acre (45 kg·ha^{-1}) using 10N-4.4P-8.3K. Okra was directed seeded on bare ground on 21 May in single row at a within-row spacing of 6 inches (0.15 m) onto 10-ft-long plots. Distance between rows was 3 ft (0.9 m), which created a stand of 14,520 plants/acre (35,941 plants/ha). Plants were sidedressed with 100 lb/acre (112 kg·ha^{-1}) of 10N-4.4P-8.3K on 8 and 24 July. Okra was harvested three times each week between 16 July and 12 Aug. for a total of 11 harvests. At each location, early yield was determined by adding the production of the first three harvests. Total marketable yield was determined by adding the marketable production of all the harvests. Monthly marketable yields were also calculated. For comparison, average marketable weight per harvest was also calculated by dividing total marketable weight by the number of harvests.

In Trial 3 (NFREC-00), plant height and pod harvest parameters were also measured on 6 June. Plants in each plot were blindly evaluated on a consensus basis by three experienced okra harvesters. Ease of picking was rated on a 0 to 2 scale based on the subjective effort necessary to separate pods from the plants. Ratings of 0 and 2 corresponded to easy and difficult, respectively. The spininess rating scale was 0 for no spines, 1 for few spines, and 2 for many spines based on touching the foliage during harvest. The ease-of-finding rating was based on the subjective difficulty encountered to locate the pods on the plant based on foliage density and pod position on the plant: 0 and 2 corresponded to pods visible without touching the plant, and pods completely hidden in the canopy, respectively. These three indices were aimed at comparing cultivars

Table 1. Seed source, earliness, and pod color of selected okra cultivars.

Cultivar	Seed source[z]	Days to harvest[y]			Pod color/shape
		Listed	Seeded	Transplanted	
Annie Oakley II (F1[x])	1	48	33–59	40	Green, Ridged
Baby Bubba (F1)	2	53	40–64	40	Green, Ridged
Big Un (OP)	8	NA	42	---	Green, Ridged
Burgundy (OP)	3	60	40-59	---	Red, Ridged
Cajun Delight (F1)	3	52	33–59	40	Green, Ridged
Clemson Spineless (OP)	1,4,5	55	40–62	40	Green, Ridged
Clemson Spineless 80 (OP)	6	58	62	40	Green, Ridged
Cowhorn (OP)	11	57	64	---	Green, Smooth
Emerald Green (OP)	6,8	55	35–62	40	Green, Smooth
Green Best (F1)	3,7	48	56	40	Green, Ridged
Lee (OP)	3	56	59	40	Green, Ridged
Long Green Pod (OP)	12	50	---	42	Green, Ridged
Louisiana Green Velvet (OP)	8	58	62	42	Green, Smooth
Mita (F1)	8	49	45–59	40	Green, Ridged
North & South (F1)	10	46	62	40	Green, Ridged
Penta Green (OP)	7	50	---	40	Green, Ridged
Rani (F1)	8	46	49	---	Green, Ridged
SOK 601 (F1)	7	NA	---	40	Green, Ridged
Spike (F1)	8	48	31–59	40	Green, Ridged
White Velvet (OP)	9	60	40-52	---	White, Smooth

[z]Seed Source: 1 = Petoseed, Saticoy, Calif.; 2 = Burpee Seeds, Warminster, Pa.; 3 = Park Seed, Greenwood, S.C.; 4 = Asgrow, Tifton, Ga.; 5 = Kelly Seeds, Hartford, Ala.; 6 = Ferry-Morse, Sun Prairy, Wyo.; 7 = Sakata, Morgan Hill, Calif.; 8 = Willhite, Poolville, Texas; 9 = Montgomery Seeds, Montgomery, Ala.; 10 = SeedWay, Elizabethtown, Pa.; 11 = Shumways, Graniteville, S.C.; 12 = local store (Huffman and Gilmore, Live Oak, Fla.).
[y]Seeded = observed from seeds (three trials); transplanted = observed from transplant (one trial); (---) = mode of establishment not used.
[x]F1 = hybrid; OP = open pollinated; NA = not available.

from a harvester's point of view. A global harvest index (ranging from 0 to 6) was determined by adding the ease-of-picking rating, ease-of-finding rating, and spininess rating.

At all locations, the experimental design was a randomized complete block design with four replications. All data were analyzed with analysis of variance and means were compared using Duncan's multiple range test at the 5% level (SAS, 2000). Overall cultivar comparison was done using ranks for early and total marketable yields from each location. The number of times a cultivar appeared in the top 25% of each trial was counted. Using ranks allowed to compensate for the different number of entries in each trial and different plant populations, and still make it possible to establish an overall comparison of cultivars. A similar method was used to compare sweet corn cultivars (Simonne et al., 1999b). Early rank (ER) was determined for each entry by multiplying by 100 the sum of the ranks of early yield when a cultivar was among the top 25% of each trial. Season rank (SR) was determined for each entry by multiplying by 100 the sum of the ranks of total marketable yields when a cultivar was among the top 25% of each trial. As early yield is as important as total marketable yield in determining the overall potential of a cultivar, the overall rank (OR) was determined as ER+SR. Thus, OR ranged between 0 and 200. We selected the OR value of 132 as the cut off value for top cultivars. A OR of 132 occurs for a cultivar which ranked in the top 25% two out of three times it was ranked. The calculation of ER , SR and OR took into account the number of time each cultivar was evaluated so that cultivars that were evaluated more often were not given an advantage over those which were evaluated less often.

The economical comparison open-pollinated (OP) or hybrid cultivar? was done by comparing the median cost of open-pollinated seeds to that of hybrids. The yield benefit of using hybrid cultivars was calculated, for each trial, as the average yield of OP and of hybrid cultivars, divided by the number of harvests. Based on 8,000 seeds/lb (17,621 seeds/kg), an 80% germination rate, a 1-lb/acre (1.12-

Table 2. Early, monthly, and total marketable yield of selected okra cultivars grown on bare ground with drip irrigation at the North Alabama Horticulture Substation in Cullman, Ala., in 1998 (NAHS-98) and a commercial field in Suwannee County, Fla., in 2000 (COMM-00).

	Marketable wt (lb/acre)[z]				
Cultivar	Early	July	August	Total	Avg
Trial 1 (NAHS-98)[y]					
Annie Oakley II	278 a	3,919 a	1,258 ab	5,176 a	370
Clemson Spineless	0 a	2,568 b	1,915 a	4,483 ab	320
Cajun Delight	256 a	2,987 ab	1,035 b	4,022 ab	287
Spike	361 a	2,695 ab	987 b	3,683 abc	263
White Velvet	182 a	1,795 b	1,122 b	2,917 bc	208
Emerald Green	13 a	1,811 b	1,004 b	2,815 bc	201
Burgundi	20 a	2,056 b	628 b	2,684 bc	192
Baby Bubba	38 a	1,668 b	441 b	2,109 c	151
R^{2x}	0.39	0.50	0.47	0.49	
CV	136	34	49	33	
P	0.07	0.01	0.02	0.02	
Trial 4 (COMM-00)[w]					
Green Best	1,946 a	2,923 a	4,135 a	7,867 a	715
Mita	758 b	1,882 ab	4,291 a	6,412 a	583
Spike	1,017 ab	1,547 ab	3,820 a	5,858 a	533
Annie Oakley II	383 b	1,503 ab	4,167 a	5,818 a	529
Burgundy	355 b	1,172 b	4,454 a	5,742 a	522
Lee	618 b	1,751 ab	3,501 a	5,563 a	506
Baby Bubba	534 b	1,838 ab	3,641 a	5,543 a	504
North & South	343 b	1,443 ab	3,090 a	4,570 a	416
Clemson Spineless 80	523 b	1,488 ab	2,951 a	4,447 a	404
Clemson Spineless	160 b	1,268 ab	2,708 a	4,007 a	364
Cajun Delight	387 b	1,256 ab	2,488 a	3,876 a	352
Cowhorn	60 b	622 b	2,767 a	3,413 a	310
Lousiana Green Velvet	108 b	554 b	2,193 a	2,767 a	256
Emerald Green	40 b	714 b	1,878 a	2,600 a	236
R^{2x}	0.40	0.39	0.31	0.36	
CV	148	82	74	72	
P	0.02	0.04	0.24	0.10	

[z]1 kg·ha^{-1} = 0.89 lb/acre; within columns, means followed by different letters are significantly different according to Duncan's multiple range test (5% level); both trials were direct seeded.
[y]In trial 1, early yield was calculated as the sum of yields on 5, 7, and 9 July; total marketable yield was calculated as the sum of yields on 5, 7, 9, 12, 14, 16, 19, 21, 23, 26, 28, 30 July, and 1, and 3 Aug.
[x]R^2 = coefficient of determination calculated as the model sum of squares/total sum of squares; CV = coefficient of variation; *P* = probability ($F > F_{obs}$).
[w]In trial 4, early yield was calculated as the sum of yields on 16, 19 and 22 July; total marketable yield was calculated as the sum of yields on 16, 19, 22, 24, 27, 29 July, and 1, 3, 6, 8, 12 Aug.

kg·ha^{-1}) seeding rate, a target population of 9,000 plants/acre (22,277 plants/ha), and costs of $5/lb ($11/kg) for open-pollinated and $100/lb ($220/kg) for hybrid cultivars, estimated seed costs were $7/acre ($17/ha) and $140/acre ($347/ha) for open-pollinated and hybrid cultivars, respectively. Using $0.75/lb ($1.65/kg) retail value, the increase in yield needed to offset the cost of hybrid seeds would be +180 lb/acre [(140-7)/0.75; 202 kg·ha^{-1})]. The economical comparison bare ground or plasticulture production? was done by comparing the cost of production under both systems for the three cultivars that were included in all four trials ('Annie Oakley II', 'Spike', and 'Clemson Spineless'). Drip irrigation was used in both production systems. The additional costs for the plasticulture was assumed to be due to the fumigation [$150/acre ($371/ha)], the plastic mulch itself [$180/acre ($446/ha)], and the cost of plastic removal after the okra crop [$75/acre ($187/ha)]. Using the same $0.75/lb ($1.65/kg) retail value, the increase in yield needed to offset the cost of plasticulture would be +540 lb/acre [(150 + 180 + 75)/0.75; $605/ha].

Results and discussion

Relative earliness. Days to maturity (DTM) available from commercial literature ranged from 46 days after planting for 'Rani' and 'North & South' to 60 d for 'Burgudy' (Simonne et al., 2000). As observed for most vegetable crops, hybrid cultivars needed fewer days to reach production than open-pollinated cultivars did. In our trials, DTM from transplants were 40 to 42 d, while those from seed tended to be slightly less than those reported in the commercial literature (Table 1).

Pod yield. Because number of entries, number of harvests in each test, and plant populations were different among tests, data were analyzed and discussed separately by test. In Trial 1 (NAHS-98), significant differences in early marketable yield were found among the eight entries for July ($P = 0.01$), August ($P = 0.02$) and total marketable yield ($P = 0.02$) [Table2]. Differences in early yield were not significant ($P = 0.07$) as high variabil-

Table 3. Early, monthly and total marketable yield of selected okra cultivars grown with plasticulture at the North Alabama Horticultural Substation in 1999 (NAHS-99) and North Florida Research and Education Center, Suwannee Valley in 2000 (NFREC-00).

	Marketable wt (lb/acre)[z]					
Cultivar	Early	May	June	July	Total	Avg
Trial 2 (NAHS-99)[y]						
Annie Oakley II	430 a	---	1,644 a	4,708 a	6,353 a	635
Spike	456 a	---	1,459 a	2,784 b	4,243 b	424
Emerald Green	47 b	---	701 cd	3,149 b	3,850 b	385
Clemson Spineless	16 b	---	606 cd	2,857 b	3,463 b	346
Mita	238 ab	---	1,029 bc	2,145 bc	3,174 bc	317
Rani	287 a	---	980 bc	2,173 bc	3,153 bc	315
White Velvet	5 b	---	348 d	1,361 c	1,710 c	171
R^{2x}	0.64	---	0.66	0.63	0.66	
CV	72	---	37	32	30	
P	0.01	---	0.01	0.01	0.01	
Trial 3 (NFREC-00)[w]						
Mita	1,269 a	3,683 ab	10,089 a	3,729 a	17,500 a	833
North & South	1,275 a	4,059 a	9,225 a	3,498 a	16,782 ab	799
Clemson Spineless	1,262 a	3,508 a–c	9,447 a	3,711 a	16,667 a–c	794
SOK 601	1,545 a	4,113 a	8,863 a	3,247 a	16,223 a–c	773
Green Best	1,206 a	3,274 a–d	8,898 a	3,951 a	16,123 a–c	768
Annie Oakley II	1,425 a	3,540 ab	8,417 a	3,983 a	15,940 a–c	759
Clemson Spineless 80	1,140 a	3,631 ab	8,254 a	3,449 a	15,334 a–c	730
Spike	1,377 a	3,648 ab	7,993 a	3,043 a	14,684 a–c	699
Penta Green	981 a	3,312 a–d	8,071 a	3,130 a	14,513 a–c	691
Cajun Delight	1,188 a	3,264 a–d	6,828 a	3,281 a	13,372 a–c	637
Big Un	852 a	2,141 d	8,020 a	2,501 a	12,662 a–c	603
Emerald Green	1,007 a	2,749 b–d	6,573 a	2,817 a	12,139 a–c	578
Lee	673 a	2,271 cd	7,167 a	2,695 a	12,133 a–c	578
Baby Bubba	886 a	2,473 b–d	5,623 a	3,549 a	11,645 bc	555
Long Green Pod	781 a	2,635 b–d	6,110 a	2,509 a	11,254 bc	536
La. Green Velvet	712 a	2,271 cd	5,966 a	2,872 a	11,109 c	529
R^{2x}	0.59	0.70	0.59	0.59	0.67	
CV	43	20	26	23	20	
P	0.32	0.01	0.16	0.13	0.03	

[z]1 kg·ha^{-1} = 0.89 lb/acre; Within columns, means followed by different letters are significantly different according to Duncan's multiple range test (5% level).
[y]Trial 2 was direct seeded; early yield was calculated as the sum of yields on 12, 15, and 19 July; total marketable yield was calculated as the sum of yields on 12, 15, 19, 22, 26, 29 July, and 1, 5, 8, and 12 Aug.
[x]R^2 = coefficient of determination calculated as the model sum of squares/total sum of squares; CV = coefficient of variation; P = probability ($F > F_{obs}$).
[w]Trial 3 was transplanted; early yield was calculated as the sum of yields on 17, 19 and 22 May; total marketable yield was calculated as the sum of yields on 17, 19, 22, 24, 26, 30 May, 2, 5, 8, 13, 16, 19, 21, 23, 26, 28, 30 June, and 3, 5 ,7, and 10 July.

ity was observed (CV = 136). Significantly higher July, August, and total marketable yields were observed for 'Annie Oakley II'. The standard 'Clemson Spineless' had significantly lower July yield than 'Annie Oakley II', but differences among these two cultivars in total marketable yield were not significant. July, August and total marketable yields of 'Baby Bubba' were significantly lower than those of the other entries. The white-podded cultivar 'White Velvet' tended to have yields slightly below average.

In Trial 4 (COMM-00), significant differences were found in early (P = 0.02) and July (P = 0.04) yields, but not in August (P = 0.24) or total (P = 0.10) yields (Table 2). 'Green Best' had significantly higher early and July yields [1,946 and 2,923 lb/acre (2,181 and 3,276 kg·ha^{-1}), respectively], while 'Cowhorn', 'Louisiana Green Velvet' and ' Emerald Green' had the lowest early and July yields. 'Burgundy' and 'Annie Oakley II' had the highest August yield [4,454 and 4,167 lb/acre (4,992 and 4,670 kg·ha^{-1}), respectively], while 'Green Best' and 'Mita' had the highest total marketable yield [7,867 and 6,412 lb/acre (8,817 and 7,187 kg·ha^{-1}), respectively]. In this test, average pod production per harvest ranged between 715 lb/acre (801 kg·ha^{-1}; 'Green Best') and 236 lb/acre (265 kg·ha^{-1}; 'Emerald Green'). Nine cultivars had total marketable yields greater than that of 'Clemson Spineless'.

In Trial 2 (NAHS-99), significant differences were found in early, July, August and total marketable yield (all P = 0.01) among the 7 cultivars evaluated (Table 3). Early and July yields of 'Annie Oakley II' and 'Spike' were significantly higher than those of the other entries. 'Annie Oakley II' also had significantly higher August and total marketable yields. 'Clemson Spineless' had significantly lower early and total marketable yields than 'Annie Oakley II'.

In Trial 3 (NFREC-00), significant differences were observed in May (P = 0.01) and total (P = 0.03) yield (Table 3). 'North & South' [4,059 lb/acre (4,549 kg·ha^{-1})] and 'SOK 601' [4,113 lb/acre (4,610 kg·ha^{-1})] had significantly higher May yields than the other entries. 'Mita' [17,500 lb/acre (19,614 kg·ha^{-1})] and 'North & South' [16,782 lb/acre (18,809 kg·ha^{-1})] had significantly higher total marketable yields, and 'Louisiana Green Velvet' had the lowest [11,109 lb/acre (12,451 kg·ha^{-1})]. Although large numerical values were found in early, June and July yields, these differences were not significant (P = 0.32, 0.16, and 0.13, respectively). 'Annie Oakley II' had numerically the highest early yield [1,425 lb/acre (1,597 kg·ha^{-1})], while 'Louisiana Green Velvet' had the lowest [712 lb/acre (798 kg·ha^{-1})]. In this trial, average pod production per harvest ranged between 833 and 529 lb/acre (934 and 593 kg·ha^{-1}) for 'Mita' and 'Louisiana Green Velvet', respectively. Early and total marketable yield differences in 'Clemson Spineless' and 'Clemson Spineless 80' were numerically small.

PLANT HEIGHT AND HARVEST RATINGS. Significant differences were found in plant height (P = 0.01; Table 4). Plant height ranged between 59 inches (1.5 m; 'Louisiana Green Velvet') and 17 inches (0.43 m; 'Baby Bubba'). While most heights observed were acceptable from a picking standpoint, the short, bushy growth habit of 'Baby Bubba' made it difficult to harvest, and an unacceptable choice for

Table 4. Plant height and harvest ratings of selected okra cultivars evaluated in 2000 at the North Florida Research and Education Center, Suwannee Valley, in Live Oak, Fla.

Cultivar	Plant ht (inches)[z]	Ease of picking rating[y]	Spininess rating[x]	Ease of finding rating[w]	Global harvest index[v]
North & South	28 d–f	0.0 a	0.3 c	0.0 c	0.3 c
Cajun Delight	27 d–f	0.0 a	0.3 c	0.8 a–c	1.0 bc
Clemson Spineless	35 cd	0.0 a	0.5 c	0.5 bc	1.0 bc
Mita	32 c–e	0.0 a	1.0 a–c	0.0 c	1.0 bc
Penta Green	22 f	0.0 a	0.5 c	0.5 bc	1.0 bc
Spike	36 c	0.0 a	1.0 a–c	0.0 c	1.0 bc
La. Green Velvet	59 a	0.0 a	1.3 a–c	0.0 c	1.3 bc
Green Best	29 c–e	0.5 a	0.8 bc	0.3 c	1.5 bc
SOK 601	29 de	0.5 a	0.5 c	0.5 bc	1.5 bc
Annie Oakley II	26 ef	0.5 a	0.8 bc	0.5 bc	1.8 bc
Long Green Pod	33 c–e	0.0 a	0.8 bc	1.0 a–c	1.8 bc
Big Un	44 b	1.5 a	0.5 c	0.0 c	2.0 bc
Clemson Spineless 80	30 c–e	0.5 a	1.0 a–c	1.0 a–c	2.5 a–c
Emerald Green	34 cd	0.0 a	1.3 a–c	1.8 ab	3.0 ab
Baby Bubba	17 g	1.0 a	1.8 ab	2.0 a	4.8 a
Lee	29 c–e	1.0 a	2.0 a	1.8 ab	4.8 a
R^{2u}	0.91	0.40	0.54	0.56	0.61
CV	12	192	70	104	65
P	0.01	0.13	0.01	0.01	0.01

[z]1 inch = 2.54 cm.
[y]Ease-of-picking rating scale: easy = 0; difficult = 2.
[x]Spininess rating scale : no spines = 0; few spines = 1; many = 2.
[w]Ease-of-finding rating scale: easy = 0; medium = 1; difficult = 2.
[v]Global harvest index defined as the sum of the ease-of-picking, ease-of-finding, and spininess ratings; ranges from 0 = most desirable to 6 = least desirable. Due to rounding off, not all ratings may sum to the value reported as the global harvest index.
[u]R^2 = coefficient of determination calculated as the model sum of squares/total sum of squares; CV = coefficient of variation; P = probability ($F > F_{obs}$).

commercial plantings. Yet, its small size may be more of a value in home gardens. Because of the orientation used in defining the rating scales, low ratings were more desirable than higher ratings. Significant differences were also found in all ratings (P = 0.01; Table 4) except for the ease-of-picking rating (P = 0.13). The ease-of-picking rating was the most subjective of the ratings, and therefore the variability in ratings within a cultivar were high, as expressed by the high CV (192). The spininess rating ranged between 2.0 for 'Lee' to 0 for 'North & South', 'Cajun Delight', 'Clemson Spineless', and 'Penta Green'. The ease-of-finding rating ranged from 2.0 for 'Baby Bubba' to 0 for 'North & South', 'Mita', 'Spike', 'Louisiana Green Velvet', and 'Big Un'. Low ease-of-finding rating values corresponded to plants which pods were visible on the plants. This was due to either large internodes or deeply indented leaves, or both. Although no formal data were collected on time needed to harvest, picking went faster when both the picker's hands could reach into the foliage and grab two pods at the same time. 'North & South' had a significantly lower global harvesting rating (0.3) than 'Baby Bubba' and 'Lee' (4.8). The picking parameter scales used were rather simple and limited to three values (0, 1, or 2). Yet, these results, especially those of the global harvesting rating, suggested that common okra cultivars differ by their harvestability. These characteristics are of high interest to okra producers and pickers, but, to our knowledge, have remained unquantified so far.

Overall evaluation. ER ranged between 100 for 'SOK 601' and 'Spike' to 0 for 10 cultivars ('Big Un', 'Burgundi', 'Cowhorn', 'Clemson Spineless', 'Clemson Spineless 80', ' Emerald Green', 'Long Green Pod', 'Louisiana Green Velvet', 'Penta Green', 'Rani', and 'White Velvet'; Table 5). ER for 'Annie Oakley II' was 75. Three cultivars ('Lee', 'Long Green Pod', and 'North & South') had ER values of 50. SR ranged between 100 for 'SOK 601' to 0 for 13 cultivars ('Baby Bubba', 'Big Un', 'Burgundi', Cowhorn', Cajun Delight', 'Clemson Spineless 80', 'Emerald Green', 'Lee', 'Long Green Pod', 'Penta Green', 'Rani', and 'White Velvet'). SR for 'Annie Oakley II' and 'Clemson Spineless' were 75 and 50, respectively. The OR for 'Annie Oakley II', 'Spike', 'Mita', 'North & South', 'Green Best', and 'Clemson Spineless' were 150, 150, 100, 100, 100, and 50, respectively. All five cultivars with OR values greater than 50 were hybrids. 'Clemson Spineless' had the highest OR (50) among the open-pollinated cultivars. Based on these results, 'Mita', 'Spike', 'Green Best' and 'North & South' should be added to the list of recommended cultivars. The experimental 'SOK 601' should also be included on that list, but on a for trial basis since it was evaluated only at one location (NFREC-00). This overall evaluation was aimed at identifying the best cultivars across the wide range of cultural practices (including plant population) used in our experiments.

COST ANALYSIS. Open-pollinated or hybrid seed? The mean yield for each harvest was 177, 231, 315, and 371 lb/acre (198, 259, 353, and 416 kg·ha^{-1}) for the open-pollinated cultivars and 253, 326, 364, and 519 lb/acre (284, 365, 408, and 581 kg·ha^{-1}) for the hybrid cultivars, for Trial 1, 2, 3, and 4, respectively. This corresponds to a respective average gain per harvest of +76, +95, +49, and +148 lb/acre (+85, +107, +55, and +166 kg·ha^{-1}) by using a hybrid cultivar over a open-pollinated one, or an average yield increase per harvest of +92 lb/acre (+103 kg·ha^{-1}). Under the assumption presented in the Materials and Meth-

Table 5. Overall performance of selected okra cultivars based on ranking of earliness and total marketable yield from four trials[z]

	Early yield rank[y]					Total marketable yield rank					
Cultivar	Trial 1	Trial 2	Trial 3	Trial 4	ER[x]	Trial 1	Trial 2	Trial 3	Trial 4	SR	OR
SOK 601			1*		100 (1/1)			4*		100 (1/1)	200
Spike	1*	1*	3*	2*	100 (4/4)	4	2*	8	3*	50 (2/4)	150
Annie Oakley II	2*	2*	2*	8	75 (3/4)	1*	1*	6	4*	75 (3/4)	150
Green Best			7	1*	50 (1/2)			5	1*	50 (1/2)	100
Mita		4	5	3*	33 (1/3)		5	1*	2*	66 (2/3)	100
North & South			4*	10	50 (1/2)			2*	8	50 (1/2)	100
Lee			16–	4*	50 (1/2)			13–	6	0 (0/2)	50
Clemson Spineless	8–	7–	6	11–	0 (0/4)	2*	4	3*	10	50 (2/4)	50
Cajun Delight	3		8	7	0 (0/3)	3		10	11–	0 (0/3)	0
Big Un			13–		0 (0/1)			11		0 (0/1)	0
Cowhorn				13–	0 (0/1)				12–	0 (0/1)	0
Long Green Pod			14–		0 (0/1)			15–		0 (0/1)	0
Penta Green			11		0 (0/1)			9		0 (0/1)	0
Rani		3			0 (0/1)		6–			0 (0/1)	0
Burgundi	6			9	0 (0/2)	7–			5	0 (0/2)	0
Clemson Spineless 80			9	6	0 (0/2)			7	9	0 (0/2)	0
Louisiana Green Velvet			15–	12–	0 (0/2)			16–	13–	0 (0/2)	0
White Velvet	4	6–			0 (0/2)	5	7–			0 (0/2)	0
Babby Bubba	5		12	5	0 (0/3)	8–		14–	7	0 (0/3)	0
Emerald Green	7–	5	10	14–	0 (0/4)	6	3	12	14-	0 (0/4)	0

[z]Trial 1 = 1998 trial at the North Alabama Horticulture Substation (NAHS), Cullman, Ala.; Trial 2 = 1999 trial at NAHS; Trial 3 = 2000 trial at the North Florida Research and Education Center, Suwannee Valley, Live Oak, Fla.; Trial 4 = 2000 trial in a commercial field in Suwanne County, Fla.

[y](*)Rating within the top 25% of the trial; (–)rating within the bottom 25% of the trial.

[x]ER = early ranking (0 to 100 scale); SR = season ranking (0 to 100 scale); both defined as = 100 × times in top 25%/total times evaluated OR = overall oanking (0 to 200 scale) defined as = ER + SR.

ods section, it would take two harvests for the increase in pod yield value of the hybrid cultivar to offset the increased cost of the seed over the open-pollinated cultivar ($2 \times 92 = 184$ compared to 180). As most okra plantings are harvested for a minimum of six harvests (three weekly harvests over 2 weeks), it is likely that hybrid seeds are economical for okra production.

Bare ground and drip irrigation or plasticulture? 'Annie Oakley II', 'Spike' and 'Clemson Spineless' were the only three cultivars included in all trials and they were used to compare production systems. For those three cultivars combined, average marketable total marketable yields per harvest were 403 and 599 lb/acre (452 and 671 kg·ha^{-1}) for bare ground and plasticulture production, respectively. Under the conditions outlined in the Materials and Methods section, a yield increase of +540 lb/acre (+605 kg·ha^{-1}) is needed to make the use of plasticulture economical. The mean yield increase per harvest observed in our trials was +196 lb/acre (+220 kg·ha^{-1}). Under these conditions, it would take approximately three harvests to reach break-even point. Based on these estimates, it is likely that producing okra as a double crop on plasticulture is economical. However, as production costs and okra retail values may change, it is always necessary to run cost estimates similar to these with case-specific figures.

Conclusions

A wide array of phenotypes is available among commercial okra cultivars available in the U.S. Alternative color and shapes are available along with the traditional ridged, elongated green pods. Differences in early yield tended to be not significant among cultivars. However, 'Annie Oakley II' (Trials 1 and 2), 'Mita' (Trial 3), and 'Green Best' (Trial 4) had the highest total marketable yields. In this evaluation of 20 okra cultivars, hybrid cultivars performed better than the open-pollinated ones. The hybrids 'Annie Oakley II' and 'Spike' were better overall than the other cultivars tested. The standard 'Clemson Spineless' was overall the best open-pollinated cultivar. Based on the results of these four trials, 'Mita', 'Spike', 'Green Best', and 'North & South' should be added to the list of recommended cultivars. The experimental 'SOK 601' should also be included on that list on a for trial basis. Cultivars with unusual pod shape and/or color should be used preferably for niche markets. However, as all of them are open-pollinated cultivars, their yields tended to be significantly lower than those of the hybrid standards. Given the limited importance of the okra market for seed companies, it is unlikely that hybrids with white or red pods, or with elongated or oversized pods will be commercialized. Based on three pod harvest ratings, differences were found among cultivars. 'North & South' and 'Baby Bubba' were the easiest and most difficult entries to harvest, respectively. Economical comparisons based on the yields from these trials suggested that planting a hybrid cultivar instead of an open-pollinated one, and using plasticulture (double cropping) instead of bare ground production with drip irrigation are likely to be economical for okra production.

Literature cited

Arulrajah, T. and D.P. Ormrod. 1973. Responses of okra (*Hibiscus esculentus* L.) to photoperiod and temperature. Ann. Bot. 37:331–340.

Hochmuth, G.J., D.N. Maynard, C.S. Vavrina, W.M. Stall, T.A. Kuchareck, S.E. Webb, and A.G. Smajstrla. 2000. Okra production in Florida, p. 179–181. In: D.N. Maynard and S.M. Olson (eds.). Vegetable production guide for Florida. Univ. Fla., Gainesville.

Inforzato, R. and J.B. Bernardi. 1974. Comparative study of the root system of six okra varieties. Bragantia 33:99–103.

Joshi, A.B., V.R. Gadwal, and M.W. Hardas. 1974. Okra, p. 101–107. In: J. Hutchinson (ed.). Evolutionary studies in world crops. Cambridge Univ. Press, Cambridge, U.K.

Khan, V.A., C. Stevens, and J.E. Brown. 1990. Early response of transplanted okra grown under VisPore row cover and two types of polyethylene mulch, p. 28–32. In: P.A. Dube and K. Stewart (eds.). Proc. 22nd Natl. Agr. Plastics Congr. 21–25 May 1990, Montreal, Canada.

Khan, V.A., C. Stevens, J.Y. Lu, E.G. Rhoden, M.A. Wilson, M.K. Kabwe, and Z. Haung. 1991. The influence of age of transplants, clear and black plastic mulch and VisPore row cover on okra yields, p.146–148. In: J.E. Brown (ed.). Proc. 23rd Natl. Agr. Plastics Congr. 29 Sept.–3 Oct. 1991, Mobile, Ala.

Lamont, Jr., W.J. 1999. Okra—A versatile vegetable crop. HortTechnology 9(2):179–184.

Maynard, D.N. 1987. Performance of okra cultivars in a high management cultural system. Proc. Fla. State Hort. Soc. 100:246–249.

Sanders, D.C. (ed.). 1999. 2001–2002 Alabama commercial vegetable recommendations. N.C. State Coop. Ext. Serv. Publ. AG-586.

SAS. 2000. SAS/STAT statistical analysis system manual (v.8.1). SAS Inst. Inc., Cary, N.C.

Simonne, E., E. Vinson, and A. Caylor. 1998. 'Spike', 'Clemson Spineless', and 'Annie Oakley II' best performers in okra trial, p. 8–9. Auburn Univ. Ala. Agr. Expt. Sta. Reg. Bul. 1.

Simonne, E., E. Vinson, A. Caylor, and J. Owen. 1999a. Last year's top performing okra varieties return this year, p. 27–29. Auburn Univ. Ala. Agr. Expt. Sta. Reg. Bul. 3.

Simonne, E., A. Simonne, and R. Boozer. 1999b. Yield, ear characteristics, and consumer acceptance of selected white sweet corn varieties in the southeastern United States. HortTechnology 11(3):289–293.

Simonne, E.H., R.T. Boozer, R.N. Baktiyarova, and E.L. Vinson. 2000. From artichoke to zucchini: Vegetable varieties for the Southeast—Okra, p. 65. Auburn Univ. Ala. Agr. Expt. Sta. Reg. Bul. 640.