Peanut Yield, Market Grade, and Economics with Two Surface Drip Lateral Spacings

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ABSTRACT

Surface drip irrigation laterals were spaced next to crop rows and in alternate row middles to document crop yield, market grade and gross/partial economic returns compared with non-irrigated practices. A surface drip irrigation system was installed at two sites on a Faceville (Site 1) fine sandy loam and a Greenville (Site 2) fine sandy loam with 3 and 1% slope, respectively. The cultivar Georgia Green (GG) was planted in both single and twin-row configuration while the cultivar ViruGard (VG) was planted in only a twin-row configuration. Pod yield, farmer stock grade, and partial economic returns were determined for three growing seasons (2002 to 2004). Surface drip irrigated peanut had greater yield, market grade, and gross revenue compared with non-irrigated regimes. Subtracting the cost of the drip tubing showed that laterals spaced at 0.91 m are not cost effective ($-132/ha) while those spaced at 1.83 m returned an average $120/ha compared with the non-irrigated treatment. The cultivar GG had 425 kg/ha higher pod yield compared with VG (4035 kg/ha). Within irrigated lateral treatments, peanut planted in twin-row orientation had 1% higher market grade and lower OK compared with single row orientations. Pod yield and market grade was more stable at Site 2 compared with Site 1 which was probably due to slope and aspect characteristics associated with each site and not necessarily with soil series. The use of surface drip irrigation with peanut can be economically feasible if pod yield increases by at least 675 kg/ha and growers place drip tubing in alternate row middles.

Key Words: *Arachis hypogaea*, gross revenue, partial net revenue, lateral spacing, drip irrigation.

Subsurface drip irrigation (SDI) of peanut in the humid southeast has been effective in increasing pod yield and market grade, specifically kernel size distribution of peanut (Sorensen *et al.*, 2000), when compared with non-irrigated peanut production (Lamb *et al.*, 1997). Various researchers have shown that SDI can increase crop yield and quality on tomato, *Lycopersicon esculentum*, (Bogle *et al.*, 1989; Camp *et al.*, 1989), cotton, *Gossypium hirsutum*, (Bucks *et al.*, 1988; Henggeler, 1988), and corn, *Zea mays* (Powell and Wright, 1993). Bucks and Davis (1986) listed a number of potential advantages of drip irrigation which include the conservation of water, enhanced plant growth and yield, improved application of fertilizer, reduced weed growth, and decreased energy requirements. Phene *et al.* (1992) suggested that drip irrigation can contribute to maximizing water use efficiency with negligible soil evaporation, percolation, and runoff.

Surface drip irrigation, due to its simplicity of design, has been used to irrigate vegetables and high value crops for many years (Bucks *et al.*, 1974; Hanson *et al.*, 1997). It can precisely deliver water, nutrients, and chemicals to the crop root zone. One of the greatest advantages of using surface drip irrigation is that the system can be installed easily with low initial investment and provide flexible irrigation schedules without using large pumps and wells. Field tests have been conducted using drip irrigation in various crops to improve water usage. Previous research has shown that surface and subsurface drip irrigation are effective on many crops, locations, and environmental conditions with various techniques (Goldberg and Shmueli, 1970; Bucks *et al.*, 1974; Sammis, 1980; Hodgson *et al.*, 1990; Camp *et al.*, 1993; Hanson *et al.*, 1997; and Camp, 1998). Due to the increased use of irrigation in peanut production, research efforts have addressed irrigation management in peanut with respect to optimal timing and irrigation methods to suit regional production demands (Pahalan and Trapathi, 1984; Wright and Adamsen, 1993; Lamb *et al.*, 1997; Davidson *et al.*, 1998; Lanier *et al.*, 2004; and Zhu *et al.*, 2004). Bosch *et al.* (1992), O'Brien et al., (1998), and Sharmasarkar et al. (2001) using yield data and economic simulations reported that SDI would be more profitable for small areas (<30 ha) because of its lower per area investment and lower pumping costs compared to fixed or towable center-pivot systems. Subsurface drip irrigation would also be preferred

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in irregularly shaped fields where a full circle irrigation pivot cannot be installed. These areas often require drip irrigation to provide sufficient water to different irrigation zones according to the zone sizes and crop types. Little research has been done on the use of surface drip irrigation in peanut production and the effects on peanut yield and quality (Zhu *et al.*, 2004). In addition, there is a lack of information concerning the economic impact of surface drip technology on peanut production.

The objectives of this research were to: 1) show pod yield response to surface drip irrigation with two lateral spacings, 2) document farmer stock grade and gross revenue, and 3) provide a partial economic analysis of surface drip irrigation versus non-irrigation.

Materials and Methods

This research was conducted at the USDA-ARS Multi-Crop Irrigation Research Farm in Shellman, GA during the 2002 (Zhu *et al.*, 2004), 2003, and 2004 growing seasons on two soil series and topographies. Site 1 was a Faceville fine sandy loam (Fine, kaolinitic, thermic Typic Kandiudults) with up to 3% slope. The topography was undulating with a general slope towards the east with a north aspect. The soil series at Site 2 was a Greenville fine sandy loam (fine, kaolinitic, thermic Rhodic Kandiudults) with less than 1% slope.

In Site 1, three areas were selected for crop rotations of cotton, corn, and peanut. Each crop rotation was 60 m wide and 91.2 m long. Each area was split into an irrigated and non-irrigated block. There were a total of six treatments replicated three times in a randomized block design. Irrigated treatments included surface drip tube laterals spaced at 0.91 m (next to a crop row) and 1.83 m (alternate row middles). Peanut was planted either in twin or single row spacing and either irrigated or non-irrigated (planting and irrigation treatments will be described later). Individual plots were 1.83 m wide and 91.2 m long separated into six individual subplots or positions (15.2 m long) used to help identify yield versus slope interaction. Non-planted beds were used as travel rows so that once the drip tubing was installed no wheeled traffic was allowed in the plots until harvest (Zhu *et al.*, 2004).

Site 2 was part of a long term crop rotation and irrigation system project where part of a non-irrigated area was irrigated using surface drip tubing (Lamb *et al.*, 2003). The overall project was a randomized block design with six crop rotations, three irrigation systems (subsurface drip, surface drip, and overhead sprinkler) and a non-irrigated control. Each non-irrigated subplot was 18 rows wide (0.91 m row spacing) and 61 meters long. This research will only report the surface drip irrigation and non-irrigated portion of the project.

Land preparation was the same for both sites, all rotations, and for each year. The land was disk harrowed, deep ripped, and then turned with a bottom plow in late spring or early fall depending on weather conditions. Lime was applied in early spring at rates determined by soil test. In the spring a field cultivator was used for weed control, soil amendment incorporation, and soil preparation for herbicide application. Preplant herbicide, Pendimethalin (N-(1-ethylpropyl)-3, 4-dimethyl-2, 6 dinitrobenzenamine), was applied at 2.8 L/ha and incorporated with a 1.83 m wide power rototiller. Boron was applied to foliage twice each season for a total of 0.56 kg B/ha. Fungicides, insecticides, and herbicides were applied at recommended rates and timing as determined by field scouting during the growing season for disease, insect, and weed control.

Peanut cultivars Georgia Green (GG) (Site 1 and 2) and ViruGard (VG) (Site 1) were planted all years with planters centered on the 1.83-m beds. The single (Site 1) and twin-row patterns (Site 1 and 2) were planted with a commercial vacuum type planter (Monosem planter, ATI Inc, Lenexa, KS). The seeding density was 20 seed/m as recommended to reduce the risk of Tomato Spotted Wilt Virus (TSWV) (Brown *et al.*, 2002a, b). The single row planter placed seeds at 0.91 m row spacing for two rows on a bed. Twin-row pattern was planted at 1.17 m between the outside rows and 0.7 m between the inside rows with 0.22 m between the twin-rows with four rows on a bed. Aldicarb (2-methyl-2-(methylthio)-, O-((methylamino)carbonyl)oxime) was applied in each crop row at recommended rates for single and twin-row patterns.

Irrigation water was supplied through a series of 5 cm diameter flexible hoses with drip tubing connected using adapters containing shutoff valves (Agricultural Products, Inc., Ontario, CA, model 400-BV-06-LS). The drip tubing had 0.2 mm wall thickness with emitters spaced at 30 cm (Roberts Irrigation Products, Inc., San Marcos, Ca. www.robertsirrigation.com). The 0.91 m spaced lateral was about 5 cm away from the single row peanuts or placed in the center of the twin-row planted peanuts (see Zhu *et al.*, 2004). The 1.83 m spaced laterals were spaced in alternate row middles. Emitter flow rate was 0.91 L/h (2002) and 0.56 L/h (2003 and 2004). Operating pressure was 70 kPa at the head of the field (100 kPa at the pump) and

Table 1. Precipitation, irrigation, planting, and harvest dates documented for 2002 to 2004 (01 May to 30 Sept) near Shellman, GA.

Year	*Irrigation mm*	*Precip. mm*	*Plant date*	*Harvest date*
		Site 1		
2002	165	379	10 May	09 Sep
2003	114	648	06 May	11 Sep
2004	124	673	08 May	24 Sep
		Site 2		
2002	172	379	10 May	06 Sep
2003	114	648	06 May	11 Sep
2004	90	673	10 May	24 Sep

water flow was measured with mechanical water meters. Drip tubing cost $240/ha for 1.83 m lateral spacing and twice this amount ($480/ha) for the 0.91 m lateral spacing.

Research with drip irrigation has shown a water savings of about 25% (Sorensen *et al.*, 2005) compared with recommendations by Irrigator Pro (Davidson *et al.*, 2000) and Stansell *et al.* (1976). Irrigation events were determined by Irrigator Pro, but irrigation depths were reduced by an average of 82% less than recommended by Irrigator Pro. Precipitation was collected with an electronic weather station and verified with an onsite manual gauge.

Peanut maturity was determined by the hull scrape method (Williams and Drexler, 1981). Yield rows were dug with a 2-row inverter, allowed to field dry, and harvested with a two row field combine. Pod yield, farmer stock grade and kernel size distribution were determined after being mechanically dried, weighed, and adjusted to 7% moisture (wet basis) and using screens specified in USDA grading procedures (USDA, 1993). Gross revenue was determined using the USDA price table for 2005 ($/mT= $5.323 * TSMK + OK * $1.543: where TSMK = total sound mature kernels and OK = other kernels).

Data from each site is described independently. Pod yield, farmer stock (market) grade and gross revenue were analyzed using a general analysis of variance procedure (Statistix8, 2003) with respect to year, lateral spacing, and variety (Site 1). Least significant difference (LSD) method range test was used to show differences among means ($P \leq 0.05$) when *ANOVA F*-test showed significance.

Results

Precipitation received, water applied, and plant and harvest dates are shown in Table 1. Precipitation was lowest in 2002 resulting in increased irrigation compared with 2003 and 2004. Surface drip at Site 1 applied less water compared with recommendations proposed by Irrigator Pro for the overhead sprinkler associated with Site 2 by 88, 95 and 65% in 2002, 2003, and 2004, respectively (sprinkler data not shown).

Site 1. Table 2 shows ANOVA probabilities for yield, market grade (TSMK and OK) and gross revenue for Site 1 and 2. Pod yield, market grade and gross revenue were different among years and irrigation treatments. Precipitation timing and amount can account for the major yield, grade and eventual gross revenue differences between years. Pod yield, market grade and gross revenue were greater in the irrigated regimen compared with non-irrigated regime. There was no difference between cultivars for TSMK but there were differences between cultivars with respect to pod yield, OK, and gross revenue. There was no difference between row orientation for pod yield, grade parameters, and gross revenue.

Table 3 shows the yield, market grade (TSMK and OK), gross and partial net revenue determined

Table 2. ANOVA probability values for yield, market grade (TSMK and OK) and gross revenue for Sites 1 and 2.

Source	*df*	*Yield*	*TSMK*	*OK*	*Gross revenue*
			Site 1		
Year	2	0.000	0.000	0.000	0.000
Irrigation	2	0.000	0.000	0.001	0.000
Cultivar	1	0.000	0.220	0.000	0.000
Row	1	0.086	0.462	0.685	0.137
			Site 2		
Year	2	0.456	0.121	0.053	0.542
Irrigation	2	0.000	0.000	0.000	0.000

Table 3. Yield, market grade (TSMK and OK), gross and partial net revenue determined by year, lateral spacing, cultivar, and row orientation for Site 1.

	Yield	*TSMK*	*OK*	*Gross revenue*	*Partial net revenue*
Treatment	kg/ha	%	%	$/ha	$/ha
		Year			
Irrig. 2002	5046a	73.1b	4.3b	1998a	686†
Irrig. 2003	4846a	74.1a	4.9a	1953a	(53)
Irrig. 2004	3993b	72.7b	4.6ab	1580b	105
Non-irrig 2002	3565B	66.4B	9.6A	1312C	–
Non-irrig 2003	5062A	72.7A	5.5C	2006A	–
Non-irrig 2004	3769B	71.8A	6.4B	1475B	–
		Lateral spacing			
0.91 m	4747a	73.2a	3.9a	1899a	(119)‡
1.83 m	4510a	73.7a	3.7a	1804a	56
Non-irrigated	3876b	69.5b	6.7b	1478b	–
		Cultivar			
GG	4460a	72.4a	5.4a	1763a	–
VG	4035b	71.7a	4.0b	1573b	–
		Row orientation			
Single	4160a	72.3a	4.7a	1635a	–
Twin	4335a	71.9a	4.7a	1701a	–

Values in each column with the same letter (lower or upper case) are not significantly different. Lower case = irrigated. Upper case = Non-irrigated. Negative values are in ( ).

†Partial net revenue values = Irrigated gross revenue - non-irrigated gross revenue

‡Partial net revenue values = (Irrigated gross revenue - tubing cost) - non-irrigated gross revenue.

by year, lateral spacing, cultivar, and row orientation for Site 1. Irrigated and non-irrigated treatments were compared independently to show the effects of precipitation and irrigation on yield, grade, and revenue. Irrigated yield in 2004 was lower than irrigated yield in 2002 and 2003. Irrigated pod yield in 2004 was reduced due wet soil conditions that occurred at harvest. Inclement weather delayed digging by about two weeks past the optimum harvest date reducing pod yield compared to other years. Irrigated TSMK was greater in 2003 compared with 2002 and 2004. Gross revenue was greater in 2002 and 2003 compared with 2004.

Within the non-irrigated treatment, pod yield was greater in 2003 compared with the other years. Higher pod yield in 2003 was associated with precipitation timing more than the precipitation amount as there was more precipitation in 2004 but not higher yields. Peanut grade (TSMK) was greater in the higher precipitation years, 2003 and 2004, compared with 2002.

Surface drip irrigation increased gross revenue in 2002 and 2004 compared with the non-irrigated treatment. On average, irrigation increased gross revenue to the grower by $395/ha compared with non-irrigation (2002 and 2004). Sufficient precipitation in 2003 resulted in a -$53/ha loss of revenue when comparing the irrigated with non-irrigated regimen. The gross revenues for 2002 and 2004 were greater than non-irrigated treatments but may not be great enough to exceed the cost of the drip tubing and associated costs for installation.

Pod yield, market grade, and gross revenue were the same for the two lateral spacings but partial net values were not the same because of tubing costs (Table 3). Subtracting the cost of the drip tubing from the gross revenue showed the 0.91 m lateral spacing actually cost the grower $-119/ha. The 1.83 m lateral spacing had a net positive partial revenue of $56/ha.

Across both irrigated and non-irrigated treatments, pod yield of GG was 425 kg/ha greater than pod yield of VG (Table 3). There was no difference between cultivars for TSMK or gross revenue but GG had higher OK values compared with VG. Overall, GG had $190/ha more gross revenue compared with VG.

Within irrigated treatments, GG had higher yield, TSMK, and OK compared with VG (data not shown). Pod yield of GG was 530 kg/ha greater than VG and the TSMK of GG was one percentage point higher compared with VG. There was no difference in gross returns between the two cultivars with an average of $1748/ha.

There was no yield difference between row orientations at the 5% probability level, but twin row orientations did have higher pod yield at the 10% probability level (Table 2). There was no difference in OK or gross revenue with row

Table 4. Yield, market grade (TSMK and OK), gross and partial net revenue determined by year and lateral spacing for Site 2.

Source	*Yield*	*TSMK*	*OK*	*Gross Revenue*	*Partial net Revenue*
Year	kg/ha	%	%	$/ha	$/ha
		Year			
Irrig. 2002	5244a	73.7a	3.8a	2090a	613†
Irrig. 2003	5232a	75.0a	5.0a	2130a	128
Irrig. 2004	5042a	74.6a	3.8a	2030a	561
Non-irrig. 2002	3877B	69.6B	6.4A	1477B	–
Non-irrig. 2003	4995A	73.6A	5.8A	2002A	–
Non-irrig. 2004	3808B	70.8B	5.8A	1469B	–
		Lateral Spacing			
0.91 m	5105a	74.4a	4.3a	2057a	(85) ‡
1.83 m	5240a	74.5a	4.1a	2111a	209
Non-irrigated	4256b	71.4b	6.0b	1662b	–

Values in each column with the same letter (lower or upper case) are not significantly different. Lower case = irrigated. Upper case = Non-irrigated. Negative values are in ( ).

†Partial net revenue values = Irrigated gross revenue − non-irrigated gross revenue

‡Partial net revenue values = (Non-irrigated revenue − (irrigated revenue − tubing cost)).

orientation (Table 3).Within the irrigation treatments, a comparison of row orientation showed that twin-row had one percentage point higher market grade compared with single row orientations.

Site 2. Table 2 shows the ANOVA probabilities and relationships for yield, market grade (TSMK and OK) and gross revenue for Site 2. GG was the only cultivar planted and only in a twin row configuration. There were no differences in yield, grade, or gross revenue among years or lateral spacing within the irrigated treatments (Table 4). Within the non-irrigated treatment, yield in 2003 was greater than the other two years due to the timing and amount of precipitation received (described previously). The higher precipitation in 2003 also increased grade and gross revenue compared with 2002 and 2004. On average, irrigated peanut had higher gross revenues ($2083/ha) compared with non-irrigated peanut ($1649/ha). Precipitation received in 2003 decreased the difference in gross revenue between irrigated and non-irrigated treatments by $128/ha compared with an average $587 for 2002 and 2004. On average the increase in gross revenue for the irrigated treatments was $434/ha greater than the non-irrigated treatments.

There was no pod yield, market grade, or gross revenue difference between irrigated lateral spacings. Irrigated pod yield, grade, and gross revenue were greater than the non-irrigated treatment. The average irrigated pod yield was 916 kg/ha greater than the non-irrigated resulting in an average $422/ha greater gross revenue. Subtracting the cost of the drip tubing from the partial revenue value showed the 0.91 m lateral spacing actually cost the grower $-85/ha. There was a positive net partial revenue of $209/ha for the 1.83 m lateral spacing compared with the non-irrigated treatment.

Discussion

Surface drip laterals spaced in alternate row middles cost half per unit area compared with drip laterals spaced next to every crop row. Laterals spaced at 1.83 m cost about $270/ha for tubing ($0.05/m for 0.200 mm thick tubing). Average pod yield in non-irrigated peanut for these three years across both sites was 4179 kg/ha. Laterals spaced at 1.83 m had an average positive net revenue about $132/ha when subtracting the cost of the tubing compared with net revenue of the non-irrigated areas. To cover the cost of the drip tubing for the 1.83 m spacing ($270/ha) there would need to be a 675 kg/ha yield increase assuming 2005 prices. Site 1 had an irrigated to non-irrigated yield difference of 752 kg/ha while Site 2 had a yield difference of 916 kg/ha. The average yield difference between irrigated and non-irrigated sites equates to about $64/ha. This low yield difference and associated partial dollar return can be attributed to precipitation received in 2003 which increased the non-irrigated yield 1274 kg/ha compared with the average non-irrigated yield measured in 2002 and 2004. If we removed the 2003 non-irrigated yield from the non-irrigated average the difference between irrigated and non-irrigated yield be then be 1146 kg/ha or a net partial return of $188/ha or triple the partial return shown previously. Net returns for surface drip irrigation over non-irrigation are dependant on quantity and timing of precipitation and resultant yields and market grade values. However, for this three year average at both sites and across all years, surface drip irrigation for either lateral spacing may not be cost effective when accounting for installation costs, fuel, equipment, pumping energy, and system maintenance. This also assumes that drip tubing is installed every year and the old tubing is removed and destroyed.

Surface drip irrigation does not require the same infrastructure (pipe, appurtenances, filtering, etc) compared with subsurface drip irrigation (SDI) or even overhead sprinkler irrigation. In addition, this research used an irrigation percentage of about 80% of that recommended by Irrigator Pro for overhead sprinkler systems which implies water and energy savings. Previous researchers have shown that SDI is more cost effective on small fields compared with sprinkler systems (Bosch *et al.*, 1992; O'Brien et al., 1998; and Sharmasarkar et al., 2001). Since surface drip is less expensive than SDI, surface drip would be less expensive than overhead sprinkler on small fields. More research and economic analysis is needed to document the estimated savings and economic value of surface drip versus SDI versus overhead sprinkler.

Irrigated peanut with twin-row configuration had one percentage point increase in market grade and lower percentage of OK compared with single row spacing. These yield and market grade values are similar to those described by Baldwin *et al.* (2000, 2001), Beasley *et al.* (2000), Lanier *et al.* (2004) and Sorensen *et al.* (2004) for twin-row configuration.

Gross revenue for irrigated peanut at Site 1 averaged $1844 while Site 2 averaged $2083. Site 2 gross revenue was very similar to values described by Zhu *et al.* (2004) while Site 1 was $200/ha lower. Yield differences and associated revenue are probably due to differences in slope and aspect not difference in soil series. Site 1 had higher slope variation compared to Site 2 (Zhu *et al.*, 2004) such that during high intensity precipitation events water would tend to move more rapidly off Site 1 and not infiltrate compared with Site 2.

Sorensen *et al.* (2007) showed that surface drip tubing can be used in the field for longer than one season, provided the previous crops were not conventionally tilled, i.e., strip tillage or no-tillage, such that surface drip tubing was not removed. They showed that a light covering of soil or plant debris over the tubing reduced rodent damage and would allow the tubing to remain in the field for three years and possibly longer with cotton and corn rotations. Over a three year life span, tubing would cost the grower about $90/ha per year for the surface drip tubing (other infrastructure costs would be incurred). This longer life span and lower cost/ha would make surface drip feasible even during years with high precipitation.

A grower may increase revenue with surface drip irrigation on peanut using an alternate row lateral spacing (1.83 m) and twin row configuration when precipitation is limited. The increased revenue may not be high enough to pay for the cost of the tubing in one year compared with non-irrigation, especially during a wetter than normal growing season. However, if drip tubing were installed and used for previous crops (a typical rotation of cotton, corn, peanut), which implies the use of strip/no tillage, there would be greater net revenue from increased yield and market grade for irrigated compared with non-irrigated peanut. More research is needed to identify how long surface drip tubing can remain on the soil surface before replacement is required.

Literature Cited

Baldwin, J.A., E. McGriff, B. Tankersley, R. McDaniel, Crumley Brothers, G. Heard, and E. Mallard. 2000. Yield and market grade of several peanut cultivars when planted by single or twin-row patterns during 2000, pp. 38-40. *In* E.P. Prostko (ed.). 2000 Georgia Peanut Research Extension Report. Georgia Agric. Exp. Sta, Tifton, GA.

Baldwin, J.A., E.J. Williams, N. Smith, J. Todd, E. McGriff, and R. McDaniel. 2001. Georgia Green, AT-201, Georgia Hi-OL, and C99-R planted by strip tillage or conventional methods in twin versus single row patterns during 2001, pp. 89-91. *In* R.C. Kemerait, Jr. (ed.). 2001 Georgia Peanut Research Extension Report. Georgia Agric. Exp. Sta, Tifton, GA.

Beasley, J.P., J.A. Baldwin, E.J. Williams, and J.E. Paulk. 2000. Comparison of peanut cultivars planted on single, twin, and six rows per bed spacings. pp. 54-57. *In* E.P. Prostko (ed.). 2000 Georgia Peanut Research Extension Report. Georgia Agric. Exp. Sta, Tifton, GA.

Bogle, C.R., T.K. Hartz, and C. Nunez. 1989. Comparison of subsurface trickle and furrow irrigation on plastic-mulched and bare soil for tomato production. J. Am. Soc. Hort. Sci. 114:40-43.

Bosch, D.J., N.L. Powell, and F.S. Wright. 1998. Investment returns from three sub-surface microirrigation tubing spacings. J. Prod. Agric. 11:371-376.

Brown, S., J. Todd, A. Culbreath, J.A. Baldwin, J.P. Beasley, and B. Kemerait. 2002a. Managing spotted wilt of peanut. Bull. 1165R. Georgia Agric. Exp. Sta., Tifton, GA.

Brown, S.L., J.W. Todd, A.K. Culbreath, J.A. Baldwin, J.P. Beasley, and B. Kemerait. 2002b. The 2002 Tomato spotted wilt risk index for peanuts. *In* G.H. Harris (ed.). 2002. Peanut Update: 2002. Bulletin no. CSS-02-04. Georgia Agric. Exp. Sta. Athens, GA.

Bucks, D.A., L.J. Erie, and O. F French. 1974. Quantity and frequency of trickle and furrow irrigation for efficient cabbage production. Agron. J. 66(1):53-57.

Bucks, D.A., and S. Davis. 1986. Trickle irrigation for crop production, Chapter1, eds. F.S. Nakauyama and D. A. Bucks. Netherlands: Elesevier Publications.

Bucks, D.A., S.G. Allen, R.L. Roth, and B.R. Gardner. 1988. Short staple cotton under micro and level-basin irrigation methods. Irrig. Sci. 9:161-176.

Camp, C.R., E.J. Sadler, and W.J. Busscher. 1989. Subsurface and alternate-middle microirrigation for the southeastern coastal plain. Trans. ASAE 31(2):451-456.

Camp, C.R., J.T. Garrett, E.J. Sadler, and W.J. Busscher. 1993. Microirrigation management for double-cropped vegetables in a humid area. Trans. ASAE 36(6):1639-1644.

Camp, C.R. 1998. Subsurface drip irrigation: A review. Trans. ASAE 41(5):1353-1367.

Davidson, J.I. Jr., C.T. Bennett, T.W. Tyson, J.A. Baldwin, J.P. Beasley, M.J. Bader, and A.W. Tyson. 1998. Peanut irrigation management using EXNUT and MOISNUT computer programs. Peanut Sci. 25(2):103-110.

Davidson, J.I. Jr., M.C. Lamb, and D.A. Sternitzke. 2000. Farm suite – Irrigator Pro (Peanut irrigation software and users guide). Alexandria, Va: The Peanut Foundation.

Goldberg, D. and M. Shmueli. 1970. Drip irrigation - a method used under arid and desert conditions of high water and soil salinity. Trans. ASAE 13(1):38-41.

Hanson, B.R., L.J. Schwanki, K.F. Schulbach, and G.S. Pettygrove. 1997. A comparison of furrow, surface drip, and subsurface drip irrigation on lettuce yield and applied water. Agricultural Water Management 33(23):139-157.

Henggeler, J.C. 1988. Drip irrigation: Lowering installation costs, increasing yields and improving water-use efficiency. pp. 31-32. *In* J.M. Brown and D. Richter (eds.). Proc. 1988 Highlights of cotton production Res. Conf., Special Sessions: New Developments from Industry. 3–8 Jan. 1988, New Orleans. Natl. Cotton Counc. of Am., Memphis, TN.

Hodgson, A.S., G.A. Constable, G.R. Duddy, and I.G. Daniells. 1990. A comparison of drip and furrow irrigated cotton on a cracking clay soil. Water use efficiency, waterlogging, root distribution and soil structure. Irrigation Science. 11:143-148.

Lamb, M.C., J.I. Davidson, Jr., J.W. Childre, and N.R. Martin, Jr. 1997. Comparison of peanut yield, quality, and net returns between nonirrigated and irrigated production. Peanut Sci. 24(2):97-101.

Lamb, M.C., D.L. Rowland, R.B. Sorensen, H. Zhu, P.D. Blankenship, and C.L. Butts. 2003. Research at the NPRL Shellman irrigated research farm. Amer. Peanut Res. and Ed. Soc. Proc. 34:52.

Lanier, J.E., D.L. Jordan, J.F. Spears, R. Wells, P.D. Johnson, J.S. Barnes, C.A. Hurt, R.L. Brandenburg, and J.E. Bailey. 2004. Peanut response to plating pattern, row spacing, and irrigation. Agron. J. 96:1066-1072.

O'Brien, D.M., D.H. Rogers, F.R. Lamm, and G.A. Clark. 1998. An economic comparison of subsurface drip and center pivot sprinkler irrigation systems. Appl. Eng. in Agric. (14)4:391-398.

Pahalan, D.K. and R.S. Trapathi. 1984. Irrigation scheduling based on evaporation and crop water requirement for summer peanuts. Peanut Sci. 11(1):4-6.

Phene, C.J., R.B. Hutmacher, J. El Ayars, K.R. Davis, R.M. Mead, and R.A. Schoneman. 1992. Maximizing water use efficiency with subsurface drip irrigation. ASAE Paper No. 92-2090. St. Joseph, Mich.: ASAE.

Powell, N.L. and F.S. Wright. 1993. Grain yield of subsurface microirrigated corn as affected by irrigation line spacing. Agron. J. 85:1164-1170.

Sammis, T. 1980. Comparison of sprinkler, trickle, subsurface, and furrow irrigation methods for row crops. Agron. J. 72(5):701-704.

Sharmasarkar, F.C., S. Sharmasarkar, L.J. Held, S.D. Miller, G.V. Vance, and R. Zhang. 2001. Agroeconomic analysis of drip irrigation for sugarbeet production. Agron. J. 93:517-523.

Sorensen, R.B., F.S. Wright, and C.L. Butts. 2000. Pod yield and kernel size distribution of peanut produced using subsurface drip irrigation. Appl. Eng. in Agric. 17(2):165-169.

Sorensen, R.B., L.E. Sconyers, M.C. Lamb, and D.A. Sternitzke. 2004. Row orientation and seeding rate on yield, market grade, and stem rot incidence of peanut with SDI. Peanut Sci. 31:54-58.

Sorensen, R.B., C.L. Butts, and D.L. Rowland. 2005. Five Years of Subsurface Drip Irrigation on Peanut: What have we learned? Peanut Sci. 32(1):14-19.

Sorensen, R.B., R.C. Nuti, and M.C. Lamb. 2007. Rodent management for surface drip irrigation tubing in corn, cotton, and peanut. Peanut Sci. 34:32-37.

Statistix8. 2003. Statistix8 User's Manual. Analytical Software, Tallahassee, FL 32317. (www.statistix.com)

Stansell, J.R., J.L. Shepherd, J.E. Pallas, R.R. Bruce, N.A. Minton, D.K. Bell, and L.W. Morgan. 1976. Peanut responses to water variables in the southeast. Peanut Sci. 3(1):44-48.

United States Department of Agriculture. 1993. Milled Peanuts: Inspection instructions. Washington, D. C.: U. S. Department of Agriculture, Agricultural Marketing Service, Fruit and Vegetable Division.

Williams, E.J. and J.S. Drexler. 1981. A non-destructive method for determining peanut pod maturity. Peanut Sci. 8:134-141.

Wright, F.S. and F.J. Adamsen. 1993. Peanut and corn yield response to subirrigation through an existing drainage system. Appl. Eng. in Agric. 9(1):55-60.

Zhu, H., M.C. Lamb, C.L. Butts, and P.D. Blankenship. 2004. Improving peanut yield and market grade with surface drip irrigation in undulating fields. Trans. ASAE 47(1):99-106.