

Impact of Sprinkler Irrigation Amount on Peanut Quality Parameters

M.C. Lamb^{1*}, R.B. Sorensen², R.C. Nuti², D.L. Rowland³, W.H. Faircloth², C.L. Butts⁴, and J.W. Dorner⁵

ABSTRACT

Peanut quality parameters were analyzed across four irrigation levels during the 2002 through 2007 crop years. The peanut quality parameters consisted of total sound mature kernels and sound splits (farmer stock grade), shelling outturn by commercial edible size, accept and reject kernels by commercial edible size, seed germination, and aflatoxin. The four irrigation levels consisted of a full level (100%), two reduced levels (66% and 33%), and a non-irrigated control. The research was conducted at the USDA/ARS National Peanut Research Laboratory's Multi-crop Irrigation Research Farm in Shellman, Georgia. By year, significant differences in the irrigation treatments depended upon precipitation distribution for the specific quality parameters. For the average over the six years in the study, farmer stock grade was not significantly different in the 100, 66, and 33% treatments while all were significantly higher than the non-irrigated control. Total shelling outturn and total edible outturn were higher in the 100 and 66% compared to the 33% and non-irrigated treatments. Total reject outturn and total oil stock were not significantly different in the 100, 66, and 33% treatments, while all were significantly lower than the non-irrigated control. Percent seed germination did not differ across treatments. Aflatoxin in total reject outturn and total oil stock was significantly higher for the non-irrigated treatment compared to the irrigated treatments.

Key Words: irrigation, peanut quality, farmer stock grade, shelling outturn, seed germination, aflatoxin.

United States peanuts are among the highest quality peanuts in the world. Ensuring that quality is maintained during the entire production and marketing chain is a process that begins with sound agronomic production practices followed by curing, storage, processing, and manufacturing processes that maintain or improve quality through the final consumer product. In most commodities, including peanuts, quality is generally quantified

by an established grading system designed to make markets work more efficiently by providing information on product quality. The mechanism for improving quality is the series of monetary premiums and discounts assigned for specific grade factors. Grade factors are defined at various points in the U.S. during the marketing channel designed to reflect the quality of the peanuts at the next step of the marketing channel (16,20).

In peanuts, incoming farmer stock is the first point of the grading system and is based on percentages of foreign material, loose shelled kernels, sound mature kernels, sound splits, damaged kernels, other kernels, kernel moisture content, and visual detection of *Aspergillus flavus*, the fungus that produces aflatoxin. In a study addressing the effect of sample size on grade factors (8), it was shown that 98% of the value of a load is determined by the percentage of sound mature kernels plus sound splits (SMKSS). Shelled stock grades for runner-type peanuts are generally divided into five categories based primarily on kernel size consisting of jumbos, mediums, number 1s, US splits, and oil stock.

Aflatoxin is also an important quality factor for shelled stock peanuts because of the strict aflatoxin tolerances permitted for the sale of peanuts in edible markets. The potential for aflatoxin contamination imposes considerable economic cost to the U.S. peanut industry. A 4-yr study from 1993 to 1996 was conducted to estimate the net cost due to aflatoxin to the farmer, buying point, and sheller segments of the peanut industry in the southeast U.S. The farmer segment net cost due to Segregation III lots (visible *Aspergillus flavus* found during farmer stock grading) averaged \$2,595,000 per year. Buying point losses from handling Segregation III lots averaged \$532,585 annually. The yearly average net cost to the southeast sheller segment over the 4 yr period was \$22,697,737 per year. In the 4 yrs studied, Segregation III lots and aflatoxin cost the farmer, buying point, and sheller segments of the southeast U.S. peanut industry an average of \$25,825,259 annually (15).

Important requirements for successful peanut production include proper soil and climatic conditions, crop rotation, land preparation and planting conditions, fertilization, variety selection, weed and pest control, growth regulation, and adequate rainfall or irrigation (3,7,9,10,11,22). Supplemental irrigation is essential to maintaining crop yield,

¹Research Food Technologist, ²Agronomist, ³Plant Physiologist, ⁴Agricultural Engineer, ⁵Microbiologist, U.S.D.A., ARS, National Peanut Research Laboratory, 1011 Forrester Drive, S.E., Dawson, GA 39842.

*Corresponding author email: marshall.lamb@ars.usda.gov

quality and income during most years in peanut producing regions. Producers realized the importance of irrigation as irrigated acreage in Georgia has increased from 175,000 acres in 1970 to 1,655,000 in 2006 (1). However, demand for water resources due to urban expansion and interstate litigation coupled with repeated drought are collectively threatening irrigation water supplies in peanut producing regions of the Southeast U.S. Reductions in water availability for irrigation can negatively impact peanut yield and quality in the all U.S. peanut producing regions (11,13,14,17).

An 8-yr study in the southeastern peanut producing region concluded that irrigated peanut yield and quality parameters were significantly improved ($P = 0.05$) compared to non-irrigated. Irrigated peanut yield was 569 kg ha^{-1} higher than non-irrigated yields. The irrigation-associated increases in farmer stock grade (SMKSS), jumbos, and seed germination were significant ($P = 0.05$) at 2.3, 2.0, and 6.0%, respectively. Aflatoxin in the non-edible oil stock category was significantly ($P = 0.05$) reduced by 140 ppb in the irrigated fields (14). The objective of this research was to evaluate the effects of irrigation amount on quality factors of farmer and shelled stock peanuts.

Materials and Methods

Experiments were conducted during the 2002–2007 crop years at the USDA-ARS Multi-crop Irrigation Research Farm in Shellman, Georgia ($84^{\circ} 36' \text{ W}$, $30^{\circ} 44' \text{ N}$). The soil was a Greenville fine sandy loam (fine, kaolinitic, thermic Rhodic Kandiudults) with 0–2% slope. Conventional tillage practices were followed on all treatments and generally consisted of disking twice, subsoiling once, moldboard plow once, field cultivating once, and rototilling to establish seed beds and planting. The fungicide program for disease control included chlorothalonil for the first two sprays, tebuconazole for the next four applications, and chlorothalonil on the final application. The peanut cultivar was Georgia Green planted at 23 seeds m^{-1} . Plots consisted of 18, 30.5-m-long rows spaced 0.91 m apart.

Depending on soil moisture, planting dates were during the first two weeks of May each year. A split-plot design with crop rotations randomized within irrigation blocks was used to compare three amounts of sprinkler irrigation with a non-irrigated control. Irrigation was the main plot factor and crop rotations were randomly assigned to sub-plots within irrigation rate. A specially designed, 3-span, linear-move sprinkler irrigation system was in-

stalled and specific pressure regulation and nozzle placement provide irrigation amounts of 100, 66, and 33 percent (of 100 percent sufficiency) under the respective spans. Irrigation scheduling (timing and amount) in peanuts was managed by the Irrigator Pro for Peanuts expert system based on the 100 percent sufficiency treatment (6,13).

Five crop rotation sequences that included peanut, cotton, and corn were used. Three replications of each rotation sequence were included in the study consisting of: 1) continuous peanut; 2) cotton peanut alternating; 3) corn peanut alternating; 4) cotton, cotton, peanut; and 5) cotton, corn, peanut. Harvest date was determined by the peanut hull scrape method (21). Peanuts were dug with a standard 2-row peanut inverter, allowed to wind-row dry for approximately three days and harvested using a 2-row combine with a bagging attachment. Yield was taken from the two middle rows of each plot. After harvest, peanuts were cured to the marketable kernel moisture content between 7 and 10 percent. The yield sample was then riffle divided to obtain a 4500-g subsample for post-harvest evaluations. The peanut quality parameters measured included SMKSS, commercial shelling outturn (jumbos, mediums, No. 1s, U.S. splits, and oil stock), germination, and aflatoxin. Standard Federal-State Inspection Service grading procedures were followed to obtain SMKSS (23). Total kernels (TK) were also obtained from the farmer stock grade as defined by SMKSS plus loose shelled kernels plus other kernels. Commercial shelling outturn was obtained using various screen sizes (Table 1).

After shelling, samples were sorted using an electronic color sorter (Satake Scanmaster EMS RM 200S, Houston, TX) using standard industry settings. Electronic color sorting segregated the shelled stock lots into accepts and rejects within each shelled outturn category. Total edibles are defined as the sum of accept jumbos, mediums, No. 1s, and US splits; and total rejects are defined as the sum of reject jumbos, mediums, No. 1s, and US splits. A 250-g sample of whole kernels collected on the 0.635×1.905 -cm slotted screen was obtained and sent to the Georgia Seed Laboratory in Tifton, GA for seed germination testing.

Peanut quality factors were subjected to analysis of variance using a general linear model procedure of SAS (version 9.2, Statistical Analysis Systems, Cary, NC) and significant differences among means for year and irrigation amount were determined using Fisher's Protected Least Significant Difference test at $P \leq 0.05$. The effect of cropping rotation sequence was not significant

Table 1. Commercial shelling outturns for runner-type peanuts.

Outturn Category	Screen Size
Jumbos	Collected on 0.833 × 1.905-cm slotted screen
Mediums	Collected on 0.714 × 1.905-cm slotted screen
No. 1s	Collected on 0.635 × 1.905-cm slotted screen
US Splits	Collected on 0.675-cm round screen
Oil Stock	Fall through 0.675-cm round screen + damaged kernels + loose shelled kernels not recovered into edible

and was removed from the statistical model to allow greater replication. Unless otherwise stated, all differences described below are significant at $P=0.05$.

Results and Discussion

Precipitation and irrigation applied during the 2002–2007 growing seasons for peanut is provided in Table 2. The 20-yr average precipitation during the growing season for the region is 566 mm per year. Precipitation on peanut during the 2002–2007 growing seasons averaged 609 mm, with 3 years (2002, 2006, and 2007) receiving less than average precipitation and 2003, 2004, and 2005 receiving more than average precipitation. Irrigation amounts were approximately the same in 2002, 2006, and 2007 at 174 to 188 mm ha⁻¹. Less irrigation was applied from 2003 to 2005 at 74 to 115 mm ha⁻¹. In the three yrs with less than average precipitation, 1.8 times more irrigation was applied than in years with more than average precipitation.

Analysis of the data over the 2002–2007 crop years indicated no significant differences in peanut quality parameters associated with the crop rotation sequences. Thus, the rotation sequences were pooled and the data analyzed for peanut quality differences associated with different amounts of irrigation. The ANOVA results varied for the Year (Y) and Irrigation (I) main effects and the Y × I interaction effect for the peanut quality variables (Table 3). Year had a significant influence on SMKSS, TK, TR, germination, oil stock, and jumbo accept kernels. Irrigation amount significantly influenced TK, total edible kernels, oil stock, jumbo accept kernels, medium accept kernels, number one accept kernels. The Y × I interaction had a significant influence on SMKSS, TK, TR, total edible kernels, germination, oil stock, and jumbo accept kernels.

For all irrigation treatments, SMKSS were higher than the non-irrigated control in all years

Table 2. Precipitation and irrigation amounts for the 100% sufficiency irrigation treatment during the 2002–2007 cropping seasons at the Multi-crop Irrigation Research Farm, Shellman, GA.

Crop Year	Rainfall	Irrigation	Total
-----mm ha ⁻¹ -----			
2002	439	188	627
2003	706	109	815
2004	716	115	831
2005	854	74	928
2006	456	182	638
2007	488	174	662
Average	610	140	750

except for 2005 (Table 4). The difference in SMKSS between the 100% treatment and the non-irrigated control was 6.1% which at the current loan rate for runner-type peanuts equates to \$26.50 Mg⁻¹ higher value. This difference, although higher, is consistent with previous results obtained from farm survey data taken across a large geographic cross section of the southeast U.S. peanut belt that showed that SMKSS in irrigated peanut was higher than in non-irrigated peanut (14). No differences in SMKSS resulted in the 100%, 66%, and 33% treatments during the 2002, 2003, and 2005 years. However, differences in SMKSS between irrigation rates were observed in 2004, 2006, and 2007 years, resulting in a reduction mainly at the 33% rate compared to the higher rates (Table 4).

On average over the 6-yr period, TK were significantly higher in the 100% and 66% sufficiency treatments compared to the non-irrigated control (Table 4). No differences resulted between the 66% and 33% or between the 33% and non-irrigated treatments. Total kernels in the 100%, 66%, and 33% sufficiency treatments were higher than the non-irrigated control in all years except for 2005. No differences in TK resulted between the irrigated treatments during the 2002–2005 crop years. In 2006, TK for the 100% irrigation treatment were higher than for the 66%, 33%, and non-irrigated control treatments. In 2007, TK in the 100% and 66% irrigation treatments were higher than for the 33% treatment.

Total edibles in each of the irrigation amounts were higher than total edibles in the non-irrigated when averaged over the 6-yr period (Table 4). Reduction in amount of total edibles has a significant impact on the profitability of peanut processors (16). No differences resulted between the 100% and 66% irrigation treatments and between the 66% and 33% irrigation treatments. No differences in total edibles resulted between the

Table 3. Analysis of variance for year and irrigation amount effects on peanut quality factors.

Effect	SMKSS ^a	TK ^b	TE ^c	TR ^d	Germ ^e	OS ^f	JA ^g	MA ^h	NIA ⁱ	SSA ^j
Year (Y)	*	*	ns [†]	**	**	**	*	ns	ns	ns
Irrigation (I)	ns	*	*	ns	ns	**	**	*	**	ns
Y × I	**	*	*	*	*	**	**	ns	ns	ns

*Significant at P=0.05

**Significant at P=0.01

†ns, not significant

^aSMKSS – Sound mature kernels + sound splits^bTK – Total kernels (Sum of SMKSS, loose shelled kernels, and other kernels)^cTE – Total edible kernels (Sum of accept jumbo, medium, No. 1, and US split kernels)^dTR – Total reject kernels (Sum of reject jumbo, medium, No. 1, and US split kernels)^eGerm – Percent seed germination^fOS – Total oil stock kernels (Sum of kernels that fall through 0.675-cm round screen, damaged kernels, and loose shelled kernels not recovered into edibles)^gJA – Jumbo accept kernels (Jumbo kernels not rejected during electronic color sorting + jumbo loose shelled kernels recovered into edibles)^hMA – Medium accept kernels (Medium kernels not rejected during electronic color sorting + medium loose shelled kernels recovered into edibles)ⁱNIA – No.1 accept kernels (No. 1 kernels not rejected during electronic color sorting + No. 1 loose shelled kernels recovered into edibles)^jSSA – Sound split accept kernels (Sound split kernels not rejected during electronic color sorting + sound split loose shelled kernels recovered into edibles)**Table 4. Effect of irrigation amount on peanut quality variables during 2002–2007.**

Variable	Irrigation amount	Year ^a						AVG.
		2002	2003	2004	2005	2006	2007	
SMKSS	100	74.5a	75.5a	76.3a	62.3a	72.1a	73.2a	72.5
	66	74.2a	76.4a	75.2ab	61.8a	70.9a	71.3a	72.3
	33	74.7a	76.5a	74.6b	61.5a	68.1b	66.5b	71.1
	NI	69.6b	72.3b	70.8c	62.5a	61.7c	58.7c	66.4
Total Kernels	100	79.2a	82.0a	79.6a	74.1a	83.4a	82.6a	80.9
	66	79.3a	82.0a	78.8a	74.0a	80.0b	82.3a	79.9
	33	79.8a	81.8a	78.3a	74.0a	79.8b	78.4b	78.7
	NI	78.0b	78.1b	75.4b	73.2a	78.3b	74.4c	77.8
Total Edibles	100	69.3a	70.8a	71.9a	59.9a	71.2a	75.0a	69.7
	66	68.7a	71.1a	70.9a	59.1a	68.4b	74.5a	69.1
	33	70.0a	70.3a	69.8a	59.2a	65.3c	69.1b	67.7
	NI	64.7b	66.7b	66.7b	58.8a	63.8c	56.3c	63.8
Total Rejects	100	11.2a	11.2a	7.8a	14.7a	12.2a	7.6a	11.2
	66	10.0a	11.0a	7.9a	15.5a	12.3a	7.9a	10.8
	33	9.1a	11.5a	8.5a	15.9a	14.5b	10.6b	11.7
	NI	13.6b	13.4b	10.0b	16.0a	18.5c	18.1c	14.8
Germination	100	96.4a	96.5a	95.6a	96.2a	88.7a	94.7a	93.8
	66	95.4a	96.7a	96.0a	96.2a	88.2a	94.2a	93.8
	33	95.1a	96.2a	95.8a	95.0a	84.3b	94.7a	93.0
	NI	90.2b	96.1a	95.8a	95.0a	85.6b	92.0b	92.7
Total Oil Stock	100	5.4a	7.1a	5.2a	13.2a	6.4a	5.0a	6.8
	66	6.0a	6.6a	5.1a	12.6a	6.6a	5.6a	7.1
	33	5.2a	6.4a	5.1a	12.4a	9.0b	7.9b	7.6
	NI	8.1b	8.4b	7.5b	12.4a	14.7c	17.2c	11.2

^aMeans within columns followed by the same letter are not different at (P≤0.05) according to Fisher's Protected Least Significant Difference test.

Table 5. Effect of irrigation amount on shelling outturns for runner-type peanuts over years from 2002 to 2007.

Irrigation Amount ^a	Jumbos		Mediums		Number 1s		Sound Splits	
	Accepts	Rejects	Accepts	Rejects	Accepts	Rejects	Accepts	Rejects
100%	16.7a ^b	0.55a	34.7a	0.12a	6.1a	0.50a	10.6a	0.53a
66%	15.3ab	0.59ab	33.1ab	0.12a	6.8a	0.53a	10.9a	0.60a
33%	14.1b	0.66b	31.8b	0.13a	7.1a	0.55ab	11.3a	0.61a
NI	10.1c	0.69bc	28.5c	0.16b	13.1b	0.66c	10.9a	0.75b

^aSufficiency (%), NI=non-irrigated.

^bMeans within columns followed by the same letter are not different at ($P \leq 0.05$) according to Fisher's Protected Least Significant Difference test.

irrigated treatments during the 2002–2005 crop years. In 2006, total edibles for the 66% sufficiency treatment were intermediate between the 100% irrigation treatment and the 33% and non-irrigated treatments. In 2007 total edibles in the 100% and 66% treatment were higher than the 33% treatment and the non-irrigated control (Table 3).

On average over the 6-yr period, total rejects were higher in the non-irrigated treatment compared to all of the irrigated treatments (Table 4). No differences in total rejects resulted between the irrigated treatments during the 2002–2005 crop years. Total rejects in the 100%, 66%, and 33% irrigation treatments were lower than the non-irrigated control in all years except for 2005. No differences in total rejects resulted between the irrigated treatments during the 2002–2005 crop years. In 2006 and 2007, no differences in total rejects resulted in the 100% and 66% treatments while total rejects in both of these treatments in each year were lower than the 33% treatment.

No differences resulted for seed germination when averaged across the 6-yr period. This result was unexpected and not consistent with prior research that showed a significant difference in seed germination from samples gathered at harvest from a large geographic cross section of the southeast U.S. peanut belt (14). A possible explanation for the lack of response to irrigation is that the research plots had Ca levels of $1,258 \text{ kg ha}^{-1}$ which is 2.4 times higher than the 525 kg ha^{-1} recommended soil test level. The amount of Ca taken up by the plant is dependent on concentration levels in the soil and the amount of available water (18). In the years when rainfall was below normal (2002, 2006, 2007), seed germination was higher in the irrigated treatments compared to the non-irrigated treatment (Table 4). No differences in seed germination in the irrigated amounts resulted except in 2006 where the 100% and 66% treatments were higher than the 33% treatment.

Averaged over the 6-yr period, no significant differences resulted among the irrigation amounts for total oil stock while all were lower than the non-

irrigated control (Table 4). Total oil stock in the 100%, 66%, and 33% treatments was lower than the non-irrigated control in all years except for 2005. Oil stock prices are approximately 40% lower than edible peanut prices and thus the increased output of oil stock in non-irrigated peanuts has a negative impact on the profitability of peanut processors (16). No differences in total oil stock resulted between the irrigated treatments during the 2002–2005 crop years. In 2006 and 2007, total oil stock in the 33% irrigation treatment was higher than the 100% and 66% treatments.

Irrigation amount had significant impacts on post harvest processing through effects on shelling outturns and total shelled stock value per ton (Table 5). The data provided in Table 5 are the percentage of accepts and rejects for each commercial runner-type outturn category on a net shelled stock ton basis averaged across the 6-yr study period. Jumbo accepts in the irrigation treatments were higher than the non-irrigated control. No differences resulted between the 100% and 66% treatments or the 66% and 33% treatments, and the 100% treatment was higher in jumbos than the 33% treatment. Within the jumbo outturn, the 100% irrigation treatment had less rejected jumbos than the non-irrigated control. No differences resulted between the 66%, 33%, and non-irrigated treatments. The trends in the medium accepts outturn category were similar to the jumbo accepts category. Rejects in the mediums were higher in the non-irrigated control and no differences in medium rejects resulted in the irrigated amounts. In the No. 1s accepts category, the non-irrigated control had more No. 1s than any of the irrigation amounts. No differences resulted in No. 1 accepts for the irrigated amounts. The rejects in No. 1s were higher in the non-irrigated control and no differences resulted in No. 1 rejects in the irrigation amounts. No differences resulted for sound split accepts. However, sound splits are generally functions of handling and kernel moisture during processing instead of irrigation amount (3,5).

Sound split rejects were higher in non-irrigated control compared to the irrigation amounts, and no differences resulted between the irrigation amounts.

Aflatoxin analyses were conducted separately for the accept and reject samples. Due to variability associated with aflatoxin, the samples for jumbos, mediums, no. 1s, and sound splits were combined and quantified using liquid chromatography (19). No aflatoxin was detected in either the accepts or rejects from any of the irrigated treatments. In the non-irrigated control, aflatoxin was detected in the accepts in 2002 at 10.2 parts per billion. Aflatoxin was detected in the non-irrigated rejects in 4 yr, however, the only significant level was 17.4 ppb found in 2002. While 3 yrs of the study received less than average precipitation, drought stress apparently was not sufficient for significant contamination levels to occur (4).

Summary and Conclusions

The data indicate the importance of peanut irrigation in Georgia on peanut quality factors. Significant differences resulted in all quality factors, except seed germination, for the 100% irrigation amounts versus non-irrigated control over the study period (2002–2007). Shelling outturn of higher value kernel categories (jumbos and mediums) were significantly higher in the 100% irrigation amounts than resulted in the 33% irrigation amount and the non-irrigated control. Results of this research show the importance of irrigation on peanut quality beyond the farm gate impacting the post-harvest processing sector of the peanut industry.

Literature Cited

1. Anon. 2006. Irrigation survey reflects steady growth. *Irrigation Jour.*, Jan./Feb., pp. 24-39.
2. Beasley, E.O. and J.W. Dickens. 1963. Engineering research in peanut curing. *North Carolina Agric. Exp. Stn. Tech. Bull.* No. 155.
3. Beasley, J.P. 1990. Producing quality peanuts. *Univ. of Georgia Coop. Ext. Serv. Bull.* 1036:5-10.
4. Blankenship, P.D., R.J. Cole, T.H. Sanders, and R.A. Hill. 1984. Effect of geocarposphere temperature on pre-harvest colonization of drought-stressed peanut *Aspergillus flavus* and subsequent aflatoxin contamination. *Mycopathologia* 85:69-74.
5. Davidson, J.I. Jr., T.B. Whitaker, and J.W. Dickens. 1982. Grading, cleaning, storage, shelling, and marketing of peanuts in the United States, pp. 571-623. *In* H.E. Pattee and C.T. Young (eds.). *Peanut Science and Technology*. Amer. Peanut Res. Educ. Asso., Yoakum, TX.
6. Davidson, J.I. Jr., C.L. Butts, S. Parker, and C.A. Jones. 1990. EXNUT: An expert system for peanut production. *ASAE Paper No. 90-7557*. Amer. Soc. Agric. Eng., St. Joseph, MI.
7. Davidson, J.I. Jr., P.D. Blankenship, R.J. Henning, W.R. Guerke, R.D. Smith, and R.J. Cole. 1991. Geocarposphere temperature as it related to Florunner peanut production and irrigation patterns and soil temperature. *Peanut Sci.* 18:79-85.
8. Dowell, F.E. 1992. Sample size effects on measuring grade and dollar value of farmers' stock peanuts. *Peanut Sci.* 19:121-126.
9. Henning, R.J., J.F. McGill, L.E. Samples, C. Swann, S.S. Thompson, and H. Womack. 1979. *Growing Peanuts in Georgia: A Package Approach*. Univ. of Georgia Coop. Ext. Serv. Bull. 640, 488 pp.
10. Henning, R.J., A.H. Allison, and L.D. Tripp. 1982. Cultural practices. pp. 123-127. *In* H.E. Pattee and C.T. Young (eds.). *Peanut Science and Technology*, Am. Peanut Res. and Ed. Soc, Inc., Yoakum, TX.
11. Johnson, C. 1987. *Georgia peanut production guide*. SB23. The Univ. of Georgia College of Agriculture Extension Service.
12. Jordan, D.L., J.E. Bailey, J.S. Barnes, C.R. Bogle, S.G. Bullen, A.B. Brown, K.L. Edmisten, E.J. Dunphy, and P.D. Johnson. 2002. Yield and economic return of ten peanut-based cropping systems. *Agron. J.* 94:1289-1294.
13. Lamb, M.C., J.I. Davidson, Jr., and C.L. Butts. 1993. Peanut yield decline in the Southeast and economically feasible solutions. *Peanut Sci.* 20:36-40.
14. 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 non-irrigated and irrigated production. *Peanut Sci.* 24:97-101.
15. Lamb, M.C. and D.A. Sternitzke. 2001. Cost of aflatoxin to the farmer, buying point, and sheller segments of the southeast United States peanut industry. *Peanut Sci.* 28:59-63.
16. Lamb, M.C., P.D. Blankenship, T.B. Whitaker, and J.W. Dorner. 2003. Processing costs and derived demand for screened versus unscreened farmer stock peanuts. *Peanut Sci.* 30:60-63.
17. Lamb, M.C., M.H. Masters, D. Rowland, R.B. Sorensen, H. Zhu, P.D. Blankenship, and C.L. Butts. 2004. Impact of sprinkler irrigation amount and rotation on peanut yield. *Peanut Sci.* 31:108-113.
18. Mengel, K. and E.A. Kirkby. 1982. *Principles of plant nutrition*. Int. Potash Inst., Berne, Switzerland.
19. Sobolev, V.S. and J.W. Dorner. 2001. Cleanup procedure for determination of aflatoxin in major agricultural commodities by liquid chromatography. *J. AOAC.* 85(3):642-645.
20. Tomek, W.G. and K.L. Robinson. 1981. Price differences associated with quality. *Agricultural Product Prices* 2:140-149.
21. Williams, E.J. and J.S. Drexler. 1981. A non-destructive method for determining peanut pod maturity. *Peanut Sci.* 8:134-141.
22. Womack, H., J.C. French, F.A. Johnson, S.S. Thompson, and C.W. Swann. 1981. *Peanut pest management in the southeast*. Univ. of Georgia Coop. Ext. Serv. Bull. 850:7-20.
23. USDA, *Agricultural Marketing Service*. 1991, *Farmers Stock Peanuts, Inspection Instructions*. U.S. Gov. Print. Office, Washington, DC.