Peanut Irrigation Management Using EXNUT and MOISNUT Computer Programs[1]

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ABSTRACT

Economic benefits from irrigating peanuts in the humid Southeast are often marginal or negative because proper consideration must be given to the complex relationships of plant, soil, pest and weather. Computer programs EXNUT and MOISNUT were developed to consider these complex relationships and to recommend timely irrigation of peanuts. A 3-yr study was conducted to evaluate the feasibility of using these computer programs for scheduling peanut irrigation on sandy and medium textured soils in Georgia. During 1994-1996, irrigation was applied two to nine times as recommended by these two computer programs. Net returns to irrigation were $490/ha higher for irrigated plots with these two programs than for nonirrigated plots. Serious compaction problems negated irrigation benefits in 1994 on the medium textured soil, and poor fertility and high disease pressure on the sandy soil negated irrigation benefits in 1995. Without these problems, the average benefit was $920/ha. During 1996, the irrigation benefits from using EXNUT and MOISNUT programs and the fungicide Folicur averaged $1098/ha and $1011/ha for sandy and medium textured soils, respectively. On the average, market grade of the irrigated peanuts were higher than for the nonirrigated peanuts. No aflatoxin (<1 ppb) was found in edible grade peanuts where these computer programs were used to manage irrigation. Based upon this study and previous research, the EXNUT and MOISNUT computer programs are very useful for scheduling irrigation on peanuts. Proper use of these computer programs should minimize the negative aspects of irrigation for fields with high disease pressure and fields that produce plants with shallow root systems.

Key Words: Computer strategies, expert systems, fungicides, irrigation scheduling.

Irrigation is necessary in most peanut (*Arachis hypogaea* L.) growing regions to minimize economic and food safety risks and to provide high quality peanuts (14). Timing and amounts of water applied are usually based upon the farmers experience and information supplied by the Cooperative Extension Service (1, 12). Based upon a 12-county study in Georgia (5), the timing and amounts of water applied by irrigation vary extensively from farm to farm. Computer-based programs that consider complex relationships of plant, soil, pest, and weather to yield and quality offer potential for improving peanut irrigation scheduling thereby reducing water application variability.

The feasibility of using computer programs to schedule irrigation for peanuts will vary directly with the benefits of irrigation. The need (20) and benefits of

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irrigation will depend upon the climate, uniformity of rainfall and crop year. In an 8-yr study (1971-1978) in Florida (13) using soil moisture sensors to schedule irrigation, the feasibility of irrigating Florunner and Florigiant peanuts was marginally economically feasible as severe droughts occurred only 2 out of 8 yr. In a 4-yr study (1980-1983) in Virginia (24) using a water balance model (16) described by Ritchie (17, 18) to schedule irrigation, irrigation was not economically feasible. In a more recent 8-yr study (15) in the Southeast USA (1987-1994), irrigation of peanuts by commercial farmers was economically feasible. In this latter study, irrigation provided $90.49/ha net returns over total cost as compared to nonirrigated production.

Changes in the peanut program of the more recent farm bill mandates a constant quota support price of $677/mt through the year 2002. However, other crop prices and production costs are not constant and their variability must be considered when making investment decisions.

The purpose of this paper is to present the results of a 3-yr study (1994-1996) to access the success of the two computer programs for managing irrigation on peanuts and to include economic analysis to show the feasibility of using computer programs EXNUT (6, 7, 9) and MOISNUT (21, 22) to schedule irrigation for peanuts. EXNUT is an expert system developed at the National Peanut Research Laboratory for the user to make decisions on how to irrigate, scout, and apply fungicides for peanuts through a series of basic questions concerning weather, soil type, soil water, irrigation capacity, field yield potential, soil temperature in the geocarposphere, planting date, current date, and crop condition. MOISNUT, a spreadsheet based, check-book type system developed by Agricultural Engineering Dept. at Auburn Univ., helps the user manage soil moisture using basic soil, irrigation and crop information specific to each field.

Materials and Methods

The experimental design was a randomized complete block with three treatments and six replications. Experiments were conducted on a sandy type, Group I (9) soil and on a medium type Group II (9) soil. The sandy type Group I soil was characterized as Americus loamy sand (sandy, siliceous, thermic Rhodic Kandiudults), and the medium type Group II soil was characterized as a Tifton sandy loam (fine loamy, siliceous, thermic Plinthic Kandiudults). The Americus and Tifton soils had average water-holding capacities in the top 1.2 m of 7.9 and 16 cm, respectively. EXNUT and MOISNUT treatments were scheduled by the computer programs and irrigation results were compared to the nonirrigated control. Plots were six rows of Florunner peanuts that were 15.2 m long, planted on 0.91-m wide row spacing. Buffer plots and alleys were used to prevent surface and underground moisture movement between test plots.

A small cable towed irrigation system was built specifically for applying water to the small plots. A frame was designed to carry two parallel booms spaced 2 m apart and mounted perpendicular to row direction on four 0.51-m diam. spoked wheels. The plot irrigation system supplied water to six rows using nine wide angle full cone (FL-10VS) spray tips at a flow rate of 25.7 L/min and pressure of 138 kPa. The irrigation systems were moved through the plots with a variable speed gear motor and cable system. A safety switch automatically closed a water supply valve and stopped the gear motor when unattended. Water for the system was supplied by a 10.2-cm diam. well.

Irrigation system design and spray row patterns were established to prevent traffic from affecting the two middle rows. These two rows were used for collecting model inputs of soil moisture measurements at (22.9- and 45.7-cm depths) maximum-minimum soil temperatures at 5.1-cm depth, and harvest data. Soil moisture measurements were made with Water Mark sensors (Model 200.5) while soil temperatures were made with 10.2-cm max-min stem thermometers. Rainfall and/or irrigation amounts were recorded and entered along with max-min soil temperatures for EXNUT and soil moisture readings for MOISNUT. Field visits to collect the data were made as instructed by each program. Recommendations made by both programs for irrigating, were followed on the respective test plots. Recommendations made by EXNUT for applying fungicides and scouting (pest alerts) were followed on all nonirrigated and irrigated plots.

Land preparation and other crop production practices were used as recommended by the Univ. of Georgia Cooperative Extension Service. Prior to crop year 1994, crop rotation and fertility practices on the sandy type soil were marginal at best and yield potential was considered below average. The sandy soil had a fallow and peanut crop rotation while the medium soil had a wheat/fallow, corn, and peanut crop rotation. During 1996, Folicur was applied as recommended by the Georgia Cooperative Extension Service for control of soilborne diseases. To obtain maximum user input to improve the programs, a research technician unfamiliar with peanut irrigation and computer programs was selected to conduct the experiments and prepare the yearly reports published in the 1994, 1995, and 1996 Georgia Peanut Research and Extension Reports (2, 3, 4). Field observations and data were collected during the preplant, growing, and harvesting periods. After harvest and drying, the yield, shelling outturns, seed germination, and aflatoxin contamination levels were determined by standard procedures (10). Aflatoxin content of the edible kernels was assumed to be 0 (<1 ppb), unless aflatoxin of the oil stock [loose shelled kernels (LSK) + small and broken kernels + damaged kernels] exceeded 100 ppb. If aflatoxin of oil stock exceeded 100 ppb, aflatoxin content of the edible kernels was determined.

The data were analyzed by the General Linear Models Procedure (GLMP), analysis of variance (PROC ANOVA), and means separated by Duncan's Multiple Range Test (19) to determine if the differences produced by the irrigation treatments were statistically significant at the $P = 0.05$ level of significance.

Results and Discussion

Significant interactions ($P \leq 0.05$) of soil, year, and irrigation treatment were observed for essentially all dependant variables. Thus, the data are first presented and discussed for each crop year and site.

Crop Year 1994. Except for May and 11-31 August 1994 was a very wet season and very little irrigation was needed or recommended by EXNUT and MOISNUT.

Rainfall was excessive at times, especially on 7 July when rain from tropical storm Alberto totaled 25 cm in 24 hr. From planting to harvest, total rainfall exceeded 82 and 95 cm on the Tifton and Americus soils, respectively. Some rainfall and irrigation data are presented in Tables 1 and 2. Although these programs recommended irrigation three to six times, only two irrigations were applied as recommended by EXNUT and MOISNUT and less than 7 cm was applied at either site. On the Americus soil, EXNUT recommended two additional irrigations and MOISNUT four additional irrigations, but rainfall occurred before application of water. On the Americus soil all irrigation applications appeared to be timely because 2 or 3 d after irrigation the peanut plants in the buffer and nonirrigated plots began to show signs of drought stress. On the Tifton soil, EXNUT recommended irrigation one additional time but rain occurred the next day. On the Tifton soil, MOISNUT recommended an early irrigation of 2.26 cm that was not needed because soil moisture was near field capacity. Irrigation was not applied and soil classification input to MOISNUT was revised to correct the error. Two faulty soil moisture sensors used by MOISNUT had to be replaced on the Tifton soil after tropical storm Alberto. MOISNUT recommended two additional irrigations on the Tifton soil but rain occurred prior to initiating irrigation.

All irrigations were not effective on some plots on the Tifton soil because runoff occurred due to soil compaction. A hardpan on the outside plots had resulted from loading semitrucks with corn in the prior crop year (1993) (see Fig. 1). This hardpan promoted runoff and restricted root growth resulting in early plant stress and low yields. EXNUT requires a check with a special soil penetrometer for hardpan or restrictions to root penetration prior to planting and at 10-25 d after planting. The inexperienced user, however, did not check for hardpan until late in the growing season. The severity of the hardpan was inversely related to the yields. The irrigated treatments had more plots with severe hardpan than did the nonirrigated control. On the plots that did not have a moderate-severe hardpan (unshaded plots in Fig.1), the yield of the irrigated plots averaged 269 kg/ha higher than the yield of the nonirrigated plots. Had EXNUT requirements for a check of hardpan and root penetration been made, the recommendations by EXNUT would have minimized the effect of hardpan by deep tillage prior to planting or by softening the hardpan with irrigation during the dry period in May to allow the roots to penetrate the hardpan and provide a deeper and better root system.

On the Americus soil, sample analyses showed low calcium (136 ppm), potassium (10 ppm), and magnesium (17 ppm). A small peanut canopy and poor lateral root system resulted even though recommended rates of gypsum (560 kg/ha), potassium (67 kg/ha), and magnesium (28 kg/ha) were applied.

The peanut yields, grades, and economic returns reflected the effects of the hardpan on the Tifton soil and the poor fertility of the Americus soil (see Fig. 2 and Tables 3 and 4). Few significant differences were noted in the data on the Americus soil. EXNUT plots provided a significantly lower percentage of oil stock peanuts and a higher grade (SMK+SS and TK) than obtained from peanuts grown in the nonirrigated plots. On the Americus soil, MOISNUT-managed plots also provided a significantly higher grade (SMK+SS and TK) than obtained for the nonirrigated plots. On the Tifton soil, the nonirrigated peanuts had a significantly higher percentage shelling outturn of jumbo size seed, and a higher grade (SMK+SS) than obtained

Table 1. Rainfall and irrigation data for Americus loamy sand.

Year	Rainfall	Water applied through irrigation		No. irrigations		Total rain received within 3 d of irrigation	
		EXNUT	MOISNUT	EXNUT	MOISNUT	EXNUT	MOISNUT
	cm	—— cm ——				—— cm ——	
1994	>95.0[a]	7.1	4.9	2	2	0	0.5
1995	46.8	25.7	13.9	7	5	11.8	6.9
1996	36.3	18.0	9.7	9	3	8.1	4.6
Avg	>59.4[a]	13.5	9.6	6	3.3	6.6	4.0

[a]In 1994 tropical storm Alberto provided more rainfall than the rain gauges would hold.

Table 2. Rainfall and irrigation data for Tifton sandy sand.

Year	Rainfall	Water applied through irrigation		No. irrigations		Total rain received within 3 d of irrigation	
		EXNUT	MOISNUT	EXNUT	MOISNUT	EXNUT	MOISNUT
	cm	—— cm ——				—— cm ——	
1994	>82.0[a]	5.5	5.0	2	2	0	1.3
1995	30.6	17.6	17.9	5	8	4.7	7.5
1996	34.0	8.9	19.4	2	8	2.1	12.7
Avg	>48.9[a]	10.8	14.1	3	6	2.3	7.2

[a]In 1994 tropical storm Alberto provided more rainfall than the rain gauges would hold.

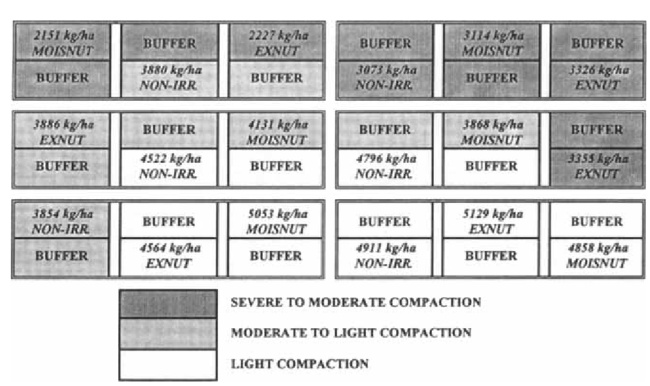

Fig. 1. Locations of compacted areas from previous years in test plots on the Tifton sandy loamy soil and the effect on yields in crop year 1994.

from the peanuts grown in the EXNUT-managed plots. Although not always significant, EXNUT-managed plots had the lowest incidence of soilborne diseases (white mold and Rhizoctonia) (see Tables 5 and 6). EXNUT recommendations for pest alerts and for scheduling fungicide applications for leaf spot were timely as pest control on all plots was excellent.

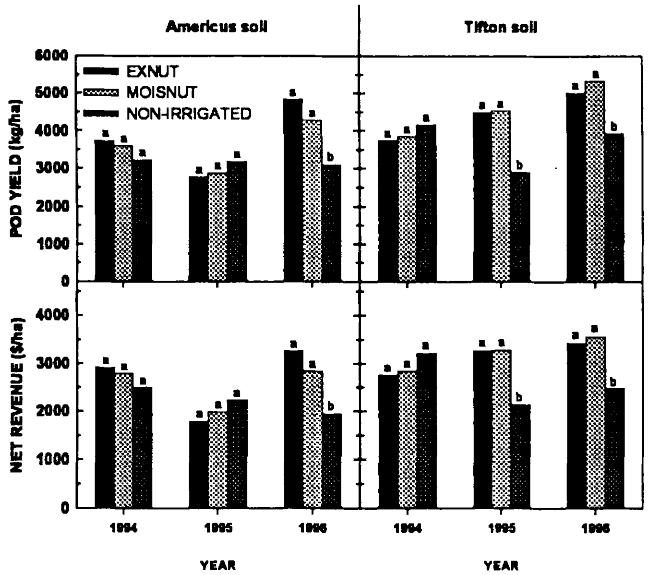

Fig. 2. Peanut pod yield and crop value response to management of irrigation by EXNUT and MOISNUT for Americus loamy sandy and Tifton sandy loam during 1994, 1995, and 1996.

The economics (net revenue, $/ha), based on estimated operating cost of irrigation by a center pivot, are shown in Fig. 2. Gross revenues less irrigation cost on Americus soil for the nonirrigated were $298 and $423/ha less than when MOISNUT and EXNUT, respectively, were used. On Tifton soil the net return to irrigation (gross revenue minus variable cost of irrigating) for MOISNUT and EXNUT were $367 and $464/ha lower than for the nonirrigated, respectively. Compaction on ends and edges of the field during prior crops on the Tifton soil site had the greatest effect on the yields, grades, and economic returns. Very low aflatoxin levels were found in oil stock in 1994. More detailed information on crop year 1994 results of this study is available in the 1994 Georgia Peanut Research-Extension Report (2).

Crop Year 1995. Crop year 1995 had average amounts of rainfall, but less than for crop year 1994. Total rainfall varied from 30 cm on the Tifton soil to 46 cm on the Americus soil. Rainfall often occurred unexpectedly and sometimes immediately after irrigation. Irrigation was applied five to eight times (Tables 1 and 2). Adequate soil moisture on both soils was maintained by timely rains until early June. On the sandy type Americus soil there were weak areas in some plots which were noticeable by stunted plant growth. Soil and plant samples taken in the weak areas and healthy areas indicated that in the weak

Table 3. Performance of EXNUT and MOISNUT as measured by grade, shelling outturns, germination, and aflatoxin contamination of peanuts on an Americus loamy sand.

Treatment	SMK+SS	TK	Jumbos	Germination	Aflatoxin[a]
	%	%	%	%	ppb
			1994		
EXNUT	73.9a[b]	78.9a	26.2a	88.3a	8.1a
MOISNUT	73.1b	78.7a	24.1a	89.7a	8.0a
Nonirrigated	72.4c	78.2b	24.8a	87.5a	10.1a
LSD (0.05)	0.6	0.4	2.4	4.5	2.3
			1995[c]		
EXNUT	63.1b	76.1a	10.1a	85.3a	0.7a
MOISNUT	65.9a	76.4a	10.9a	80.5a	1.0a
Nonirrigated	65.2a	75.0b	7.7b	79.2b	1.6a
LSD (0.05)	2.0	0.9	1.9	4.7	1.4
			1996		
EXNUT	72.1a	77.1a	20.0a	60.3a	6.7a
MOISNUT	70.1a	75.3ab	17.5b	52.2a	5.0a
Nonirrigated	65.2b	73.1b	13.3c	57.0a	48.3a
LSD (0.05)	2.3	2.7	1.9	18.1	45.6

[a]Aflatoxin contamination of oil stock (damaged, broken, and small kernels).

[b]Means in the same column and grouping followed by the same letter are not significantly different.

[c]Heavy pressure from white mold caused excessive yield losses in irrigated plots.

Table 4. Performance of EXNUT and MOISNUT as measured by grade, shelling outturns, germination, and aflatoxin contamination of peanuts on a Tifton sandy loam.

Treatment	SMK+SS	TK	Jumbos	Germination	Aflatoxin[a]
	%	%	%	%	ppb
			1994		
EXNUT	68.5b[b]	76.3a	6.3b	90.2a	8.4a
MOISNUT	69.1ab	78.5a	9.7ab	92.0a	7.0a
Nonirrigated	71.9a	77.5a	11.6a	91.2a	6.3a
LSD (0.05)	3.2	2.4	4.2[c]	3.1	2.2
			1995		
EXNUT	68.6a	77.2a	12.8a	89.2a	0.8a
MOISNUT	68.8a	76.2a	13.7a	89.2a	0.7a
Nonirrigated	69.1a	77.3a	8.3b	81.3b	1263.0b[d]
LSD (0.05)	4.1	3	2.3	3.9	672.6
			1996		
EXNUT	72.1a	77.4a	12.4a	89.3a	4.1a
MOISNUT	70.1a	77.2a	9.5b	91.0a	3.3a
Nonirrigated	65.0b	74.2b	11.6ab	88.3a	4.0a
LSD (0.05)	4.1	1.0	2.5	4.4	1.1

[a]Aflatoxin contamination of oil stock (damaged, broken, and small kernels.

[b]Means in the same column and grouping followed by the same letter are not significantly different.

[c]Excessive variability resulted from compaction (in prior years) in several irrigated plots (see Fig. 1).

[d]Aflatoxin in the edible peanuts from the nonirrigated plots on the Tifton soil averaged 14 ppb.

Table 5. Performance of EXNUT and MOISNUT as measured on an Americus loamy sand.

Treatment	White mold[a]	Rhizoctonia[b]	Pod loss[c]
	no.	%	kg/ha
1994			
EXNUT	2.3a[d]	2.7b	397 a[d]
MOISNUT	5.5a	4.7ab	555 a
Nonirrigated	6.0a	7.2a	371 a
LSD (0.05)	4.7	4.0	233
1995			
EXNUT	44.2a	0.3a	1623 a[e]
MOISNUT	47.8a	0.7a	1380 a[e]
Nonirrigated	25.7b	1.5a	832 a
LSD (0.05)	12.3	6.3	819
1996			
EXNUT	5.2a	0.7a	459 a
MOISNUT	3.8a	1.5a	555 a
Nonirrigated	2.2a	1.5a	559 a
LSD (0.05)	3.7	2.0	294

[a]Number of disease loci per 30.5 m of linear row (1 locus = 1 or more diseased plants in a 0.3-m section.

[b]Rated by visual estimate of percentage of vines colonized by *Rhizoctonia solani*.

[c]Estimated loss of yield due to plant disease, peanut maturity, and or mechanical separation.

[d]Means in the same column and grouping followed by the same letter are not significantly different at P ≤ 0.05.

[e]Heavy pressure from white mold caused excessive yield losses in irrigated plots.

Table 6. Performance of EXNUT and MOISNUT as measured on a Tifton sandy loam.

Treatment	White mold[a]	Rhizoctonia[b]	Pod loss[c]
	no.	%	kg/ha
1994			
EXNUT	2.0a[d]	0.3a	678a
MOISNUT	3.5a	0.7a	594a
Nonirrigated	5.0a	1.5a	655a
LSD (0.05)	3.0	1.8	253
1995			
EXNUT	5.7a	5.1a	594a
MOISNUT	6.3a	3.3a	725a
Nonirrigated	5.2a	0.0a	204b
LSD (0.05)	12.3	6.3	224
1996			
EXNUT	3.7a	1.5a	346ab
MOISNUT	3.5a	2.3a	545a
Nonirrigated	4.2a	1.7a	197b
LSD (0.05)	2.6	1.4	264

[a]Number of disease loci per 30.5 m of linear row (1 locus = 1 or more diseased plants in a 0.3-m section.

[b]Rated by visual estimate of percentage of vines colonized by *Rhizoctonia solani*.

[c]Estimated loss of yield due to plant disease, peanut maturity, and or mechanical separation.

[d]Means in the same column and grouping followed by the same letter are not significantly different at P ≤ 0.05.

areas, zinc toxicity and low pH in the subsoil resulted in a poor root system. Examination of root growth made during the fruiting period indicated that peanut plants on the Americus soil had not developed a deep root system. Based upon the EXNUT User's Guide (23) and knowledge base, EXNUT irrigation recommendations for the Americus soil should have been modified to reduce by one-half the amount of irrigation per application. Failure by the inexperienced user to follow EXNUT prompts to check the root system and reduce the amounts of water per application is the primary reason why the irrigation amount applied by EXNUT was almost two times that applied by MOISNUT.

EXNUT called for the first irrigation on 14 June [58 d after planting (DAP)] on the Americus soil. Soil moisture was checked using the technique specified by the EXNUT User's Guide and, although there were no signs of plant stress, moisture was becoming depleted, which was verified by readings from the soil moisture sensors. The technique specified by the EXNUT User's Guide requires use of a post hole digger or penetrometer rod to evaluate the soil moisture throughout the root zone. After irrigating both EXNUT and MOISNUT plots on the Americus soil, signs of plant stress were seen within 2 d in the nonirrigated plots. EXNUT plots on the Americus soil were irrigated seven times totaling 25.7 cm and MOISNUT plots were irrigated five times over the growing season for a total of 13.7 cm of water. Irrigation that was applied on the Americus soil early in the growing season was timely, but it appeared that some of the irrigations were unnecessary in the latter part of the growing season, especially since rainfall often occurred immediately after irrigation (3). Failure to use EXNUT recommendations for a shallow root system and the 9.9-cm rain within 3 d of an EXNUT irrigation on 24 July were certainly detrimental to the EXNUT-managed plots. The effect of the differences in the amounts of irrigation between EXNUT and MOISNUT plots on the Americus soil could not be determined because of losses due to the high percentage of white mold (*Sclerotium rolfsii*) hits in the irrigated plots (Table 5). Irrigations during the latter part of the season appeared to magnify the effects of poor fertility (zinc toxicity) and white mold. EXNUT provided pest alerts for high temperature pests on the Americus soil from 70 DAP to harvest and the need for a fungicide for soilborne diseases, such as white mold. White mold pressure and impact was severe on the Americus soil.

On the Tifton soil, MOISNUT called for irrigation 26 June, but the plots were not irrigated after receiving 2 cm of rain that day. MOISNUT plots were irrigated for the first time on 28 June (46 DAP) and EXNUT plots were irrigated for the first time on 7 July (55 DAP). Examination of root growth on the Tifton soil showed peanut plants had developed an adequate root system.

MOISNUT plots on Tifton soil received eight irrigations for a total of 18.0 cm and EXNUT plots received five irrigations for a total of 17.5 cm. Assuming a deep root system, EXNUT normally recommends 1.5 times more water per application than MOISNUT.

Pod yield, losses, disease, grade, and germination data are shown in Fig. 2 and Tables 3-6. There were no significant differences (P = 0.05) in pod yield among treatments on the Americus soil. It appeared that the fruit load (yield + pod loss at digging) or attainable yield for the irrigated plots were 224-560 kg/ha higher than the nonirrigated plots, but the white mold had a greater incidence on the irrigated plots. Use of a fungicide such as Folicur could have reduced yield losses. A significantly (P < 0.05) higher percentage of white mold hits were counted in the irrigated than for the nonirrigated plots, which resulted in the higher harvest losses and lower yields in the irrigated plots. On the Tifton soil, there were significantly higher yields, harvest losses, jumbo seed, and seed germination for the irrigated plots than for the nonirrigated plots. Aflatoxin contamination of the oil stock from the irrigated plots on the Tifton soil was dramatically lower than from the nonirrigated plots. The aflatoxin contamination of the edible peanuts from the nonirrigated plots averaged 14 ppb, while these from the irrigated plots were expected to be less than 1 ppb (11).

Net returns to irrigation on the Americus soil for EXNUT and MOISNUT treatments were $440 and $240/ha less, respectively, than for the nonirrigated treatment. However, net returns to irrigation on the Tifton soil for EXNUT and MOISNUT treatments were $1201 and $1223/ha, respectively, more than the nonirrigated treatments.

More detail information on the 1995 results of this study may be obtained from the 1995 Georgia Peanut Research Extension Report (3). In this report the user concluded that, "with careful monitoring of field conditions, maximum and minimum soil temperatures and soil moisture sensors, accurate predictions for irrigation can be made using EXNUT and MOISNUT". The user also reported that "experience and knowledge gained with each year's use of these programs helps the user make timely decisions".

Crop Year 1996. Plots in 1996 also received average rainfall, but was less than crop year 1994 and 1995 (Tables 1 and 2). The plots were irrigated two to nine times. Plots on the Americus soil received a total of 36 cm of rain throughout the growing season. This was supplemented with nine irrigations on the EXNUT plots totaling 18 cm with an average of 2 cm per application. MOISNUT plots on the Americus soil were irrigated three times totaling 9.7 cm averaging 3.3 cm per application. It appeared that the shallow root system prevented a drying-out of the lower soil moisture sensor and thus prevented MOISNUT from recommending irrigation as often as needed. On the Americus soil EXNUT called for irrigation the first time on 13 June (51 DAP) and MOISNUT called for irrigation the first time on 20 June (59 DAP). EXNUT called for 2.5 cm of irrigation again on the Americus soil on 17 June (55 DAP) only 4 d after the initial irrigation of 3.6 cm., indicating a need for a root check. The root check showed a shallow root system and prior to irrigating the amount of irrigation was reduced per application by the formula provided for shallow root growth in section 4.5.3. of the EXNUT User's Guide (23). This required more frequent irrigations to maintain moisture in the root zone where it could be utilized. This procedure also prevented "water-logging" (excessive soil moisture in the root zone) of the soil that would have resulted from applying large amounts of water per application to a shallow root system. This procedure can be followed by farmers with adequately designed pivot irrigation systems, but a deep root system and the normal EXNUT recommendations are much easier to follow.

MOISNUT recommended the first irrigation on the Tifton soil on 1 July (51 DAP) with 2 cm water. EXNUT recommended 3.6 cm for the first irrigation on 5 July (55 DAP). MOISNUT plots on the Tifton soil were irrigated eight times totaling 19.6 cm and averaging 2.4 cm water per application. EXNUT plots received two irrigations, totaling 8.9 cm averaging 4.4 cm water per application. The user selected the average yield potential option for EXNUT because of historical yield records of the field. Evidently this field has a yield potential that may justify using the high yield option because it was a level field with good fertility and low pest pressure. The irrigated treatments produced significantly higher yields and grades than the nonirrigated treatment on both soil types. On the Americus soil the irrigated plots also provided significantly higher shelling outturns than for the nonirrigated plots. Higher yields were usually attained with largest amount of irrigation.

Outstanding pest control was obtained by following EXNUT recommendations for scheduling fungicide applications and by using the new fungicide Folicur. Disease counts were very low in the plots where Folicur was applied. Outside the plots on the Americus soil where Folicur was not applied, observations indicated white mold counts were very high. Tomato spotted wilt virus (TSWV) was evident in late season but did not appear to adversely affect yields. Seed germination percentages of peanuts obtained from EXNUT, MOISNUT, and nonirrigated plots on the Americus soil were very low. Analysis of seed from these plots indicated calcium deficiency. Even after land plaster (561 kg/ha) was applied at blooming, calcium in the pod zone was low. Perhaps the water moved the land plaster away from the pod zone since the peanuts were planted on a slight bed. Aflatoxin contamination of the oil stock from the nonirrigated peanuts was higher than for the irrigated peanuts on the Americus soil. On the Tifton soil, the aflatoxin contamination in the oil stock was less than 5 ppb.

On the Americus soil the net returns to irrigation were $1312 and $887/ha more for the EXNUT and MOISNUT plots, respectively, than for the nonirrigated plots. Net revenue values for the Tifton soil were $945 and $1077/ha more for EXNUT and MOISNUT plots, respectively, than for the nonirrigated plots.

More detail information on these 1996 experiments can be obtained from the 1996 Georgia Peanut

Research-Extension Report (4) where the user concluded that "experience and knowledge gained with each years use of EXNUT and MOISNUT allows the user to make accurate decisions and to benefit from the optimum use of water applied through irrigation. These programs should be continually improved to implement new chemicals and to allow for unexpected situations."

Crop Year 1994-1996. As expected, the statistical analyses showed that the differences in rainfall and need for irrigation between crop years varied so much that there were significant interactions of crop year and test sites for essentially all performance parameters. Average data for all crop years and both test sites indicated that, when compared to nonirrigated, irrigation managed by these two computer programs provided higher yields (16-23%), grades (1-2%), shelling outturns of Jumbos (0-3%), seed germination (1-3%), and gross returns less irrigation cost ($315-644/ha). Irrigation to maintain soil moisture also prevented aflatoxin contamination of the edible grades, as aflatoxin in the oil stock of peanuts managed by these irrigation programs was less than 10 ppb while the aflatoxin in the oil stock of the nonirrigated peanuts averaged 222 ppb. Aflatoxin (14 ppb) was found in the edible peanuts grown in the nonirrigated plots on the Tifton soil during crop year 1995.

If the 1994 data for the Tifton soil (data confounded by soil compaction) and the 1995 data for the Americus soil (data confound by zinc toxicity and severe soilborne disease pressure) were excluded, the benefits of irrigation managed by the computer programs would essentially double. The confounding of these data by these undesirable conditions could have been minimized through education of users of these programs and by the use of fungicides such as Folicur. These computer programs can be improved by having the computer programs recognize undesirable conditions and modify the recommendations to account for these conditions.

Even though irrigation of peanuts in humid climate has been unprofitable to marginally profitable, these programs should make irrigation more economically feasible. In a 1993-1997 study in the humid climate of North Carolina (8), the yields of 20-30 fields per year managed by EXNUT averaged 1660 kg/ha higher than nonirrigated fields.

The economic analysis focused on returns to irrigation above variables cost of irrigation. This is a valid assumption for producers with existing irrigation systems considering EXNUT and MOISNUT for managing irrigation in peanuts. However, investment in irrigation requires more detailed analysis. The fixed cost associated with irrigation investment (including irrigation equipment, land and water source preparation, pipe and power unit) has been estimated to be $172.84/ha (12). On the Americus soil, net returns to irrigation over total irrigation cost for EXNUT and MOISNUT were $262.16 and $146.16/ha, respectively. On the Tifton soil the net returns to irrigation over total irrigation cost were $388.16 and $471.16/ha for EXNUT and MOISNUT, respectively.

Although EXNUT and MOISNUT effectively managed irrigation for peanut, analysis of investment in irrigation cannot be limited to the returns associated with only one crop which would comprise the rotation sequence of a particular field. The yield differences and prices associated for all crops—as well as expectations on future changes in yield, price, and production cost—must be incorporated.

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Literature Cited

1. Baldwin, J. A., and K. Harrison. 1989. Water use and relationships in peanut production. Univ. of Georgia Coop. Ext. Bull. SB23.
2. Bennett, C.T, J. I. Davidson, Jr., T. W. Tyson, J. A. Baldwin, J. P. Beasley, M. J. Bader, and A.W. Tyson. 1995. Feasibility of using computer programs for managing irrigation for peanuts. 1994 Georgia Peanut Ext. Rep., Tifton, pp. 77-87.
3. Bennett, C.T, J. I. Davidson, Jr., T. W. Tyson, J. A. Baldwin, J. P. Beasley, M. J. Bader, and A. W. Tyson. 1996. Feasibility of using computer programs for managing irrigation for peanuts. 1995 Georgia Peanut Ext. Rep., Tifton, pp. 106-113.
4. Bennett, C.T, J. I. Davidson, Jr., T. W. Tyson, J. A. Baldwin, J. P. Beasley, M. J. Bader, and A.W. Tyson. 1997. Feasibility of using computer programs for managing irrigation for peanuts. 1996 Georgia Peanut Ext. Rep., Tifton, pp. 112-121.
5. Davidson, J. I., Jr., and J. A. Baldwin. 1994. Evaluations of the Georgia version of EXNUT an expert system for managing irrigation. 1993 Georgia Peanut Res.-Ext. Rep., Tifton, pp. 45-49.
6. Davidson, J. I , Jr., P. D. Blankenship, R. J. Henning, W. R. Guerke, R. D. Smith, and R. J. Cole. 1991. Geocarposphere temperature as if related to Florunner peanut production and irrigation patterns and soil temperature. Peanut Sci. 18:79-85.
7. Davidson, J. I., Jr., C.L. Butts, S. Parker, and C. A. James. 1990. EXNUT: An expert system for peanut production. Amer. Soc. Agric. Eng. SAE Paper No. 90-7557, St. Joseph, MI.
8. Davidson, J.I. Jr., W.J. Griffin, M.C. Lamb, R.G. Williams, and G. Sullivan. 1998. Validation of EXNUT for scheduling peanut irrigation in North Carolina. Peanut Sci. 25:50-58.
9. Davidson, J. I, Jr., M. C. Lamb, C. L. Butts, E. J. Williams, and M. Singletary. 1995. Applications of expert systems in peanut production, pp 419-455. *In* H. E. Pattee and H. T. Stalker (eds.) Advances in Peanut Science and Technology. Amer. Peanut Res. Educ. Assoc., Inc., Stillwater, OK.
10. 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. Assoc., Yoakum, TX.
11. Dorner, J.W., and R.J. Cole. 1997. Distribution of aflatoxin in grade sample components farmer stock peanuts. Peanut Sci. 24:47-51.
12. Harrison, K., and A. W. Tyson. 1993. Irrigation scheduling methods. Univ. Georgia Coop. Ext. Bull. B-974.
13. Hewitt, T. D., D. W. Gorbet, and G. O. Westberry. 1980. Economics of irrigating peanuts. Proc. Soil Crop Sci. Soc. Fla. 39:135-140.

14. Henning, R.J., A.H. Allison, and L.D. Tripp. 1982. Cultural Practices, pp 123-138. *In* H. E. Pattee and C. T. Young (eds.) Peanut Science and Technology. Amer. Peanut Res. Educ. Assoc., Yoakum, TX.
15. Lamb, M. C., J. I. Davidson, Jr., J. W. Childre, and N. R. Martin, Jr. 1997. Comparison of peanut yield, quality, and net returns from irrigated production. Peanut Sci. 24:97-101.
16. Powell, N. L., B. B. Ross, and F. S. Wright. 1981. Evaluation of an irrigation scheduling system for Virginia. Proc. Amer. Soc. Agric. Eng. Irrigation Scheduling Conf., Chicago, IL. p. 73.
17. Ritchie, J. T. 1972. Model for predicting evaporation from a row crop with incomplete cover. Water Resources Res. 8:1204-1213.
18. Ritchie, J. T. 1973. Influence of soil water status and meteorological conditions on evaporation from a corn canopy. Agron. J. 65:893-897.
19. SAS. 1996. Users Guide. SAS Inst. Inc., Cary, NC.
20. Stansell, J. R., J. L. Shepard, J. E. Pallas, R. R. Bruce, N. A. Minton, D. K. Bell, and L. W. Morgan. 1976. Peanut responses to soil water variables in the Southeast. Peanut Sci. 3:44-48.
21. Tyson, T. W., and L. M. Curtis. 1989. Effective on farm irrigation scheduling in the humid southeast, pp 443-448. *In* National Water Conf. Proc., Irrigation and Drainage Division and Water Resources Planning and Management Division, July 17-20. ASCE, Newark, DL.
22. Tyson, T. W., and L. M. Curtis. 1990. Scheduling irrigation in the southeast with minimum inputs, pp. 688-691. *In* Visions of the Future. Proc. Third National Symp., Phoenix, AZ. Amer. Soc. Agric. Eng., St. Joseph, MI.
23. Users Guide-EXNUT. 1996. National Peanut Research Laboratory, Dawson, GA.
24. Wright. F. S., D. M. Porter, N. L. Powell, and B. B. Ross. 1986. Irrigation and tillage efforts on peanut yield in Virginia. Peanut Sci. 13:89-92.