Effects of water table depth on nitrogen accumulation and pod yield of peanut

P.G. Hunt, T.A. Matheny, F.S. Wright, and C.W. Doty

*ABSTRACT: Peanut is an important leguminous row crop in the Coastal Plain of the southeastern U.S. Its growth and yield are dependent upon dinitrogen fixation, a biological process that is adversely affected by water deficits or excesses. Drought and excessive rainfall in the same growing season present special problems for crop production in this region. A two-year field experiment was conducted to assess the effects of controlled drainage/subirrigation on peanut nitrogen accumulation and pod yield. The experiment was located on a lateral of the main channel in a PL-566 drainage district that was equipped with a water table management structure. Water table depths (WTD) were obtained from natural variations in the surface elevation; four, nonrandomized blocks contained WTD of 0.61, 0.76, 0.91, 1.07, and 1.22 m (2, 2.5, 3, 3.5, and 4 ft). Plots consisted of eight 15 m (49 ft) rows on 0.91 m (3 ft) spacings. Peanuts (*Arachis hypogaea *L., CV Florigiant) were planted during the second week in May. Shoots and roots were sampled from 0.30 m (1 ft) of row; shoots were analyzed for total nitrogen, and roots were assayed for dinitrogen fixation by acetylene reduction. Yields were taken from 30 m (98 ft) of row. Rainfall accumulations were 406 and 634 mm (16 and 25 in) in the first and second year, respectively. Pod yields ranged from 3.5 to 5.5 Mg ha^{-1} (1.6 and 2.5 t ac^{-1}) and were > 4.0 Mg ha^{-1} (1.8 t ac^{-1}), if WTD were < 0.91 m. Dry matter accumulation, acetylene reduction, and peanut pod yield were negatively correlated with WTD in the first year (R^2 values > 0.37), but there were no meaningful correlations between plant characteristics and WTD in the second season because sufficient rainfall had eliminated peanut water stress. However, differences in the partitioning of dry matter between the peanut vegetation and fruit produced differences in estimated net soil nitrogen accumulation. When dinitrogen fixation was assumed to provide 45 percent of the total N, estimated net N accumulations were negative and poorly correlated to depth (R^2 of 0.02) in the drier year. In the wetter year, estimates of net soil nitrogen accumulation ranged from 64 to 4 kg ha^{-1} (57 to 3.6 lb ac^{-1}), and the R^2 and slope of the linear regression of net N and WTD were 0.40 and -1.05, respectively. Thus, water table management and controlled drainage/subirrigation may offer a method that will reduce excess nitrogen and the associated nitrate pollution potential as well as stabilize peanut yield.*

PEANUT (*Arachis hypogaea* L.) is an important leguminous row crop in the southeastern U.S. Since the soils of this region are low in nitrogen, peanut and other legumes are dependent upon dinitrogen fixation or added fertilizer nitrogen. More than 50 percent of the accumulated shoot nitrogen may be derived from dinitrogen fixation, and dinitrogen fixation may be sufficient to produce a net increase in nitrogen returned to the soil [nitrogen fixed minus nitrogen removed in seed] *(10, 15)*. Leaching of excess nitrogen can present a water pollution problem, because excess water from rainfall may occur during or after the growing season. On the other hand, seasonal droughts, poor plant rooting, and soils with low water holding capacities cause frequent plant water deficits *(1, 16)*; and the subsequent reductions of dinitrogen fixation may result in a net

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Table 1. Rainfall accumulations during peanut growing season in 1983 and 1984.

Days After Planting	1983	1984
	mm	
42-46	121	143
71-73	174	332
102-104	271	464
129-132	360	612
Harvest	406	634

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negative nitrogen balance from peanut and other legumes *(10, 12)*.

The need for both drainage and irrigation can be met by controlled drainage/irrigation systems *(2, 3, 4)*. Controlled water tables can be sources of annually recharged water for surface irrigation; they can also be barriers on which subirrigation water can be perched *(5, 17)*. The ease with which plant water requirements can be met by subirrigation depends on the crop, soil characteristics, and the weather pattern. The objective of this study was to assess the effects of water table depth (WTD) on nitrogen accumulation and pod yield of peanuts in a field scale water table management system.

Materials and methods

A two-year field study was initiated in 1983 on a Portsmouth sandy loam (fine loamy, mixed, thermic, Typic Umbraqults) near Tarboro, North Carolina *(1, 13)*. The experimental area was contiguous to the main channel and a lateral channel of a PL 566 drainage district. A schematic of the controlled drainage/subirrigation system is presented in Figure 1. Since the WTDs were obtained from natural variations in the soil surface elevation, a nonrandomized block design was used. Soil depths to the water table [0.61, 0.76, 0.91, 1.07, and 1.22 m (2, 2.5, 3, 3.5, and 4 ft)], were the main treatments. Plots were conventionally tilled and received no fertilization. "Vernam" (S-propyl dipropylthiocarbmate) and "Balan" (N-butyl-N-ethyl-α–α–α-trifluoro-2, 6-dinitro-p-toluidine) were applied prior to planting at rates of 3 and 3.5 L ha^{-1} (1.28 and 1.5 qt. ac^{-1}), respectively. Plots consisted of eight 15 m (49 ft) rows on 0.91 m (3 ft) spacings. Peanuts (CV Florigiant) were planted during the second week in May each year.

Shoots and roots were sampled from 0.3 m (1 ft) of row at 42, 71, 104 and 132 days after planting (DAP) in 1983 and 46, 73, 102, and 129 DAP in 1984. Plant tops were dried at 70°C, weighed, ground to pass a 0.4 mm (.02 in) screen, and digested on a block digestor with 3 ml (.1 oz) of 30 percent H_2O_2 and 7 ml (.2 oz) H_2SO_4. Digested samples were analyzed for total Kjeldahl N on a Technicon Auto Analyzer using industrial method 334-74 W/B *(18)*. Root samples were assayed for dinitrogen fixation by the acetylene reduction assay *(8)*. Yields were taken from 30 m (98 ft) of row. Data were analyzed for linear regression by use of SAS *(14)*.

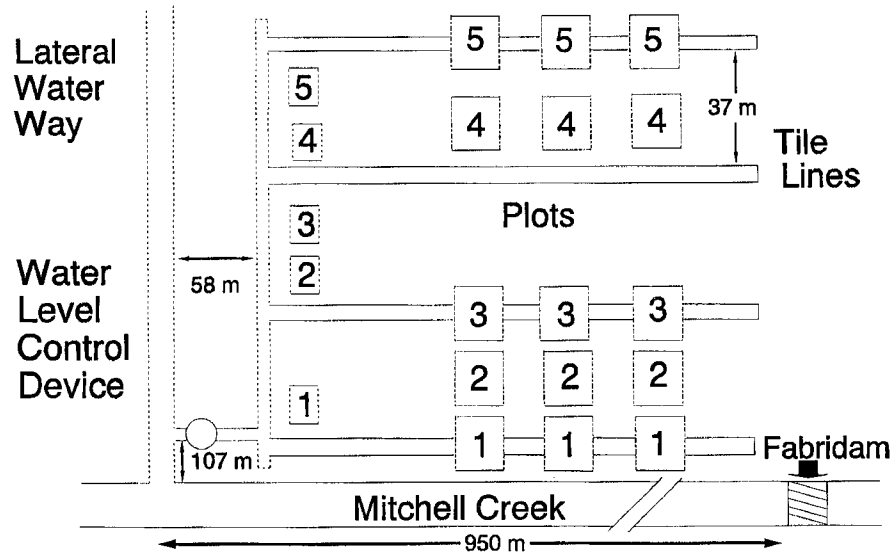

Figure 1. A schematic of the water table management experiment.

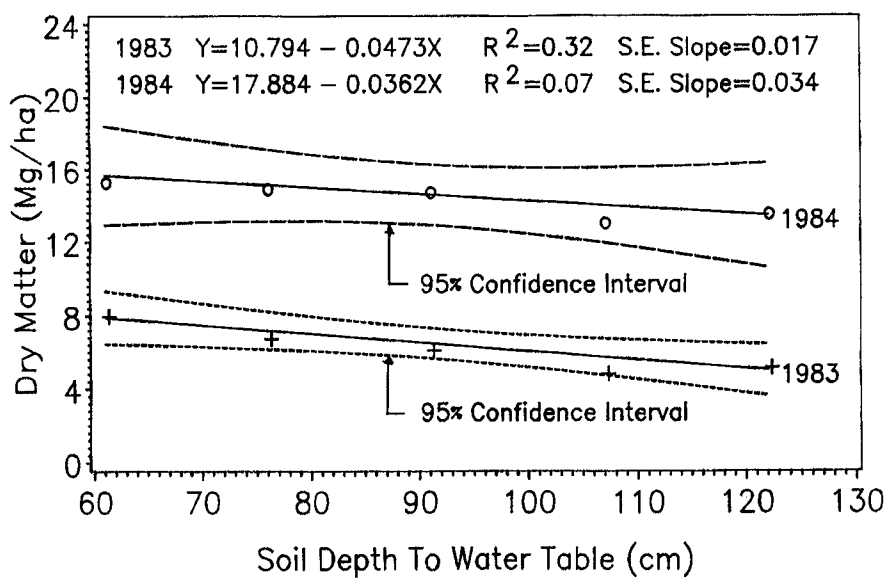

Figure 2. Linear regression of peanut dry matter accumulation at 129 to 132 days after planting vs. water table depth in a controlled drainage/subirrigation experiment.

Table 2. Linear regressions parameters for peanut dry matter in 1983 and 1984 with water table depths that varied from 0.6 to 1.2m.

Days After Planting	Year	Intercept Mg ha^{-1}	Slope	Prob. of Slope=0	R^2
42	83	2.46	-0.015	0.002	0.41
46	84	2.76	-0.014	0.008	0.41
71	83	10.65	-0.054	0.001	0.53
73	84	7.04	-0.013	0.467	0.04
104	83	19.68	-0.123	0.001	0.58
102	84	10.28	0.010	0.859	0.01
132	83	10.79	-0.047	0.017	0.32
129	84	17.88	-0.036	0.310	0.07

Table 3. Linear regressions parameters for peanut vegetative N in 1983 and 1984 with water table depths that varied from 0.6 to 1.2 m.

Days After Planting	Year	Intercept Kg ha-1	Slope	Prob. of Slope=0	R^2
42	83	97	-0.631	0.002	0.41
46	84	107	-0.616	0.004	0.45
71	83	266	-1.275	0.001	0.54
73	84	203	-0.424	0.520	0.03
104	83	384	-2.413	0.001	0.64
102	84	213	0.945	0.638	0.02
132	83	204	-0.879	0.036	0.25
129	84	466	-1.649	0.054	0.24

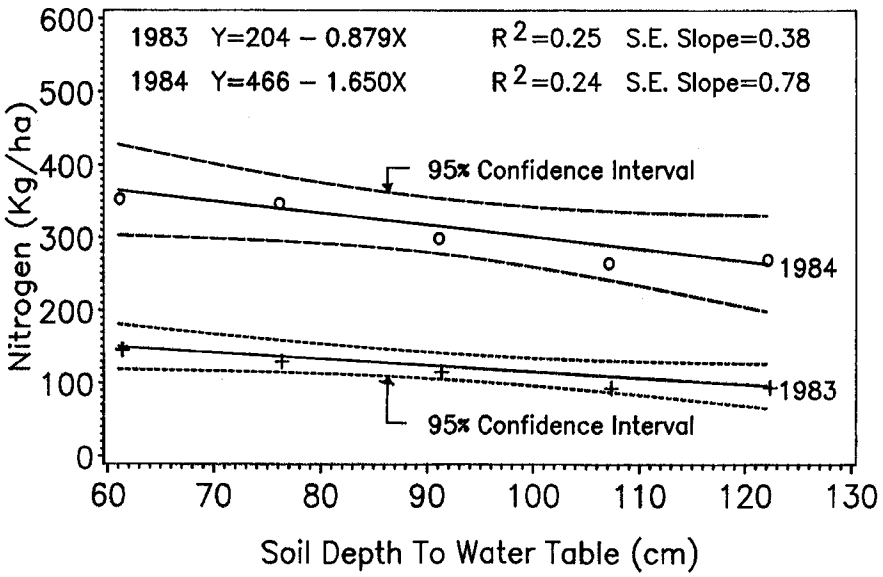

Figure 3. Linear regression of peanut shoot nitrogen at 129 to 132 days after planting vs. water table depth in a controlled drainage/subirrigation experiment.

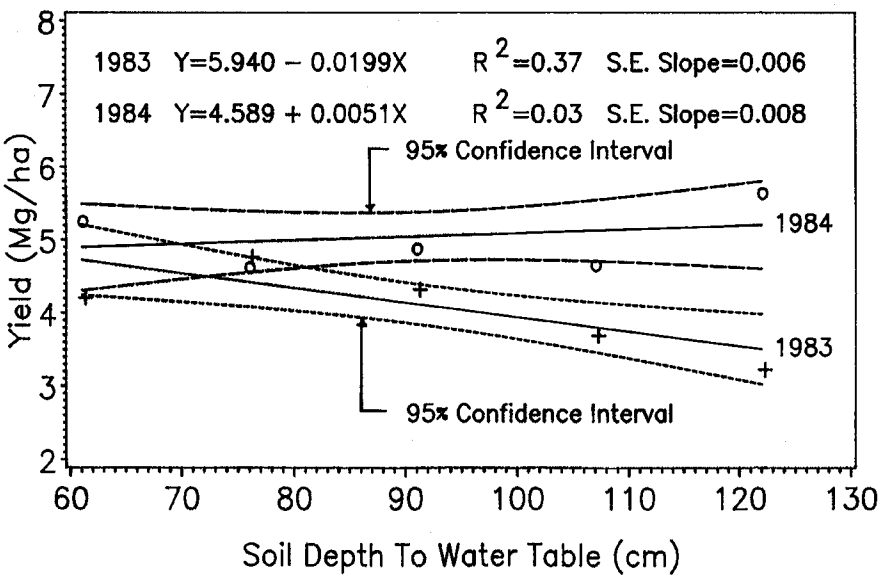

Figure 4. Linear regression of peanut pod yield vs. water table depth in a controlled drainage/subirrigation experiment.

Results and discussion

Peanut growth and pod yield. Rainfall was 406 and 634 mm (16 and 25 in) in the 1983 and 1984 growing seasons, respectively (Table 1). At 46 DAP there was relatively little difference in the accumulated rainfall between the years—121 and 143 mm (4.8 and 5.6 in) for 1983 and 1984, respectively. At that time there was a negative linear correlation for WTD with both dry matter and vegetative N accumulations in both years; R^2 values were > 0.41, and the probabilities that the slopes were zero were < 0.01 (Tables 2 & 3). However, the percent N in the vegetative tissue was not highly correlated to the WTD; R^2 values were < 0.24 (Table 4).

By 73 DAP the two years were quite different in rainfall and peanut growth-water table relationships, and these differences were even more pronounced by 104 DAP. By the later date in 1983, the R^2 values for the regression of WTD with dry matter and vegetative N were 0.58 and 0.64, respectively; and the probabilities that the slopes were zero were < 0.001. The relationship was just the opposite in 1984; R^2 values for regression of dry matter and vegetative N with WTD were < 0.02, and the probabilities that the slopes were zero were > 0.64. The correlation of percent vegetative N and WTD remained low throughout both seasons. The difference in seasonal rainfall between the two years remained at 132 DAP; maximum accumulations of dry matter and vegetative N had occurred before this time in 1983 but not in 1984. The correlation of dry matter and vegetative N with WTD was not high at this point in either year, but the correlations were stronger in 1983; R^2 values were 0.32 and 0.26 for dry matter and vegetative N, respectively.

The rate of dinitrogen fixation in peanut as measured by acetylene reduction is affected by the specific conditions at the time of sampling, e.g. temperature, light intensity, soil nitrogen content, and water. Since acetylene reduction rates were variable, they were assessed by rank analysis to reduce the variability. The linear regression correlations of the rank of acetylene reduction rate (RARR) with WTD in 1983 were low (R^2 values 0.10 to 0.16) except for those measured at 102 DAP; this R^2 was 0.41, and the probability that the slope was zero was < 0.01. As previously discussed, this sam-

ple also had the highest correlation to dry matter and vegetative N accumulation to WTD (Tables 2 and 3). In 1984 the RARR was very poorly correlated by linear regression to WTD ($R^2 < 0.01$), but the acetylene reduction rates were higher in 1984. As discussed earlier, the concentration of nitrogen in plant tissue did not vary greatly with depth to water table or year. The greater amounts of nitrogen were diluted into larger amounts of dry matter and pod yield *(11)*. The accumulations of dry matter and vegetative N at 129-132 DAP were distinctly different for 1983 and 1984 (Figure 2 and 3).

The lower rainfall in 1983 also resulted in a correlation of linear regression (R^2=0.37) between peanut pod yield and WTD (Figure 4). The more shallow WTD [< 0.91 m (3 ft)] provided sufficient water for pod yields > 4.0 Mg ha^{-1} (1.8 t ac^{-1}) even in the drier year. However, the importance of the 1.2 m (4 ft)-WTD should not be overlooked; yields from the lower depths were reasonable agronomic production levels. The rainfall of 1984 was sufficient to prevent reduction of yield by water deficit at any depth; the R^2 values for linear regression of WTD with yield was 0.03, and pod yields were > 5.0 Mg ha^{-1} (2.2 t ac^{-1}) at all depths. Wright et al. *(21)* found similar results in water management studies in Virginia; the four-year mean pod yield did not differ with WTD that varied from 0.4 to 1.2 m (1.3 to 4 ft).

It appears that water table control and subirrigation to establish a seasonally perched water table at a depth of < 0.90 m (3 ft) is a good water management strategy for peanut pod yield in a dry year. It was possible to establish this high water table because of a deeper controlled water table in the contiguous drainage channel *(1, 13)*. This drainage channel also provided the necessary drainage capacity to prevent seasonal flooding and associated crop damage in the event of very heavy rainfall.

Residual nitrogen estimates. Elimination of excess fertilization will reduce potential groundwater pollution, and this is particularly helpful in the midwestern region of the U.S. This is true because few leguminous crops make net additions of nitrogen to the high-nitrogen soils of this region *(20)*. However, leguminous crops grown on soils in the southeastern U.S. may make positive additions of nitrogen to the soil. The long growing season, warm temperatures, and low soil nitrogen are conducive to net annual increases in soil nitrogen from dinitrogen fixation, i.e. leguminous crops often add more nitrogen to the soil than is removed via their seed *(9, 10, 11)*. The availability of soil water dramatically affects dinitrogen fixation in leguminous plants and the annual nitrogen balance. It also affects the relationship between total nitrogen accumulation and the pod yield.

Specific estimates of the soil nitrogen level effect on peanut fixation were determined by Selamat and Gardner *(15)*. Dinitrogen fixation was determined to provide 65, 45, and 30 percent of the total accumulated nitrogen when 0, 60, 120 kg ha^{-1} (0, 54, 107 lb ac^{-1}) of nitro-

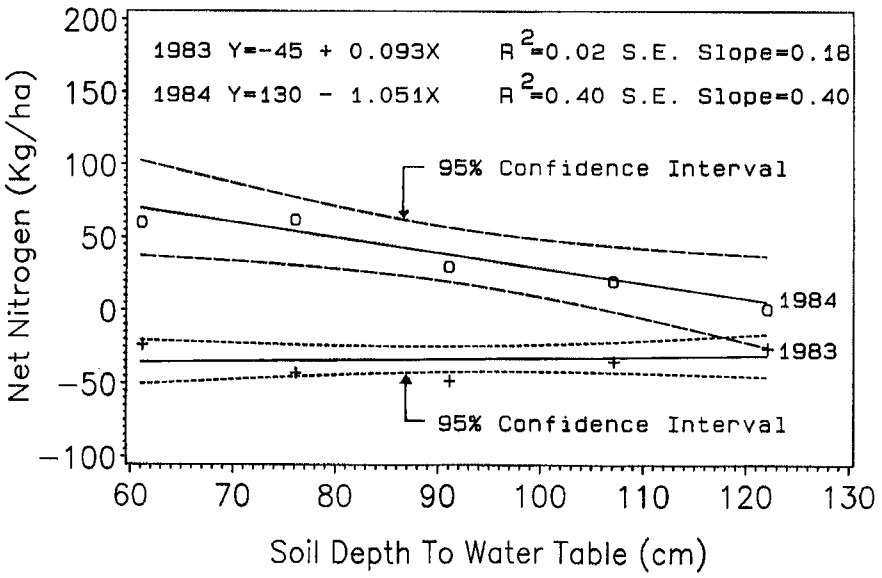

Figure 5. Linear regression of net nitrogen accumulation vs. water table depth in a controlled drainage/subirrigation experiment.

Table 4. Linear regressions parameters for peanut %N in 1983 and 1984 with water table depths that varied from 0.6-1.2 m.

Days After Planting	Year	Intercept N	Slope	Prob. of Slope=0	R^2
42	83	4.27	-0.006	0.083	0.16
46	84	4.17	-0.008	0.032	0.24
71	83	2.43	0.003	0.102	0.14
73	84	2.87	-0.001	0.928	0.01
102	83	1.90	0.001	0.893	0.01
104	84	2.18	0.004	0.101	0.16
129	83	1.90	-0.001	0.849	0.01
132	84	2.59	-0.004	0.090	0.16

Table 5. Linear regressions parameters for peanut net nitrogen accumulation in 1983 and 1984 under water tables that varied in depth from 0.6 to 1.2 m.

Assumed Percent N Fixation	Year	Intercept Kg ha^{-1}	Slope	S.E. Slope	Prob. of Slope=0	R^2
30	83	-113	0.358	0.18	0.066	0.21
	84	27	-0.780	0.32	0.031	0.31
45	83	-45	0.093	0.18	0.624	0.02
	84	130	-1.051	0.40	0.020	0.40
60	83	23	-0.172	0.22	0.448	0.04
	84	233	-1.323	0.49	0.019	0.36

gen, respectively, were applied to nodulating and nonnodulating peanut. Estimates of the annual net nitrogen (net N) in this study were calculated as follows: **[1]**

Net N=[(vegetative N+pod yield N) (% dinitrogen fixation)-pod yield N]

Assumptions: (a) pod yield = 0.72 seed + 0.28 pod wall; (b) [seed N] = 0.05, [pod wall N] = 0.014; (c) pod yield N = 0.0399 pod yield; (d) final vegetative N was equivalent to that at sampling period 4.

Regression parameters for net nitrogen vs. WTD with assumed 30, 45, and 60 percent nitrogen from fixation are presented in Table 5. The predicted net N values were negative or positive with 30 or 60 percent nitrogen from fixation, respectively, for all depths in both years. The estimated net N for conditions of 45 percent nitrogen from dinitrogen fixation are presented in Fig 5. In 1983 the linear regression R^2 for net N to WTD was 0.02, and the probability of the slope being zero was 0.62; net N was negative for all depths. In 1984 the net N and WTD were much better correlated with an R^2 of 0.40; the probability of the slope being zero was 0.02. All net N values for 1984 were positive, ranging from 66 to 2 kg ha^{-1} (59 to 1.8 lb ac^{-1}).

These estimates indicate that excess N production by peanut and the subsequent potential nonpoint nitrate pollution would be substantially affected by WTD and seasonal rainfall if the percentage of nitrogen from fixation was constant with WTD. Therefore, it would seem reasonable to think that optimal conditions for yield and nitrate reduction might be obtained by automated water table control coupled with management models or expert systems for hydrology, nitrate movement, and peanut growth. Additionally, water table control systems can also reduce stream nitrate concentrations *(6, 7, 19)*. Thus, water table management and controlled drainage/irrigation may offer a method for stabilization of peanut yield and mitigation of nitrate pollution.

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