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TRICKLE IRRIGATION OF TOBACCO

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SUMMARY:
Controlled water-nutrient management of tobacco with high-frequency trickle irrigation was used to optimize tobacco yield, quality and plant maturity rate. Results obtained could be used to recommend N-fertility based on soil characteristics, rainfall and potential evaporation, and desired growth rate. The improved tobacco quality produced a gross income increase of $427 per acre over the conventionally managed tobacco based on 1977 USDA annual support price.

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Introduction

Tobacco is seldom grown on deep sandy soils (such as Lakeland sand) because of their low water holding capacity. Because of the susceptibility of tobacco to excess water and these soils' well drained properties, it is hypothesized that these soils could offer a good growth potential for tobacco if soil water and nutrients were adequately supplied. Because 2 or 3 year crop rotation is necessary with tobacco, growers must restrict the use of 2 to 3 times the tobacco acreage to crops and chemicals compatible with tobacco. The soil used is this experiment is a deep sand (Typic Quartgipsamments - Lakeland) ranging in depth from 60 to 90 cm and underlain by a heavy red clay layer. This soil has a potential tobacco yield of 1900 kg/ha. (Soil Survey Interpretations, 9/4/69). In the past, trickle irrigation has not been used on tobacco, and in the southeast, tobacco is seldom irrigated because of the plant's ability to withstand drought for several days and the fear of rainfall following irrigation and causing aeration difficulties.

This project was conducted in cooperation with a South Carolina tobacco grower, and Clemson University Extension, and partially funded by a grant from E. I. du Pont De Nemours and Co., Wilmington, Delaware.

The objectives of this research project were to:

1. determine the influence of trickle irrigation on the yield and quality of flue-cured tobacco grown on deep sandy soil; and

2. determine optimal fertilizer-Nitrogen scheduling and application rates for trickle-irrigated tobacco.

The project was carried out over a two-year period in 1976 and 1977. In 1976, conventionally-fertilized tobacco plots were irrigated at three soil matric potential levels with a trickle irrigation system (Viaflo) similar to that used with tobacco seedbeds in previous experiments (Phene, 1976). Three fertilizer application rates were provided at the highest moisture level to determine potential growth of tobacco under optimum fertilization and moisture. In 1977, conventional fertilization of non-irrigated tobacco was compared to trickle fertilization at several N levels. Both years, conventional bed preparation was provided by the cooperative grower (Mr. C.R. Cribb and family). Each treatment was replicated 4 times and consisted of 4 rows each 150 m long with a skip row between each plot. Tobacco (*Nicotiana tabacum* L., CV Coker 347) was transplanted with a two-row planter.

1976 Research Plan

A. Irrigation Treatments:

Trickle irrigation systems (Viaflo) were used to apply water and some nutrients (treatments N_2 and N_3 only) to the tobacco crop. Immediately after transplanting, trickle tubes were installed 5 to 10 cm right of the row and covered with 5 to

10 cm of soil. Water was filtered, chemically treated and delivered to each treatment separately via a manifold consisting of a manual valve, a flow meter, a solenoid valve, a pressure regulator, a pressure gauge and a fertilizer-chemical injector (venturi-type).

The irrigation systems were controlled automatically to irrigate at the preset soil matric potential levels (M_1, M_2, and M_3) by electrical tensiometers installed on the row at 15-cm depth and a clock/timer to control the period and frequency of the irrigations. The following irrigation treatments were defined:

M_1 = irrigate when the soil matric potential (suction) was -0.10 bar or less. Period of irrigation - 30 min. and frequency of irrigation - 2 hr.

M_2 = irrigate when the soil matric potential (suction) was -0.25 bar or less. Period of irrigation - 45 min. and frequency of irrigation - 2 hr.

M_3 = irrigate when the soil matric potential (suction) was -0.40 bar or less. Period of irrigation - 60 min. and frequency of irrigation - 2 hr.

M_4 = not irrigated (rainfall only)

B. Fertilization Treatments:

Initial fertilization consisted of a broadcast application of N: 67 kg/ha; P: 134 kg/ha; K: 201 kg/ha. Subsequent applications of fertilizers were determined based on plant sample determination of fertilizer levels and Clemson University Extension recommendations. Two fertilization methods were used: conventional sidedressing (N_1) and trickle fertilization with irrigation water (N_2 and N_3). The source of N was Calcium Nitrate [$Ca(NO_3)_2$] and Potassium Nitrate (KNO_3) for the N_1, N_2 and N_3 treatments.

N_1 = applied N as a, sidedressing at conventional rate (Clemson Univ. Ext. recommendation) N: 134 kg/ha $C_a(NO_3)_2$ (25.5%N); P: 0; K: 112 kg/ha KNO_3 (15-0-14)

N_2 = applied N with trickle irrigation at conventional rate.
N_3 = applied N with trickle irrigation at 1/2 the conventional rate.

The following treatment combinations were set up for measurement purposes: M_1N_1, M_2N_1, M_3N_1, M_4N_1, M_1N_2, and M_1N_3.

1977 Research Plan

A. Irrigation Treatments:

Installation and operation of the trickle irrigation system was essentially the same as for 1976, except that the system used flow regulation rather than pressure regulation and the irrigation control was performed by an electronic irrigation controller. The system was operated at 0.75-1.0 kg/cm^2 with flow in each lateral controlled by plastic flow regulators (1.2 l/min).

Control of frequency and period of each irrigation cycle was obtained via an electronic soil moisture sensor (Phene et al., 1971) installed on the row at 15 cm depth between two tobacco plants. The sensor was connected by electrical wires to an electronic sampler/controller module (Watertech [now Moisture Control Systems, Findlay, Ohio]), which measured the soil moisture hourly, determined the need for irrigation, and switched the irrigation valves on and off for a period of one hour. The following irrigation treatments were defined:

TI = Trickle irrigated when the soil matric potential was -0.20 bar or less. The sampling frequency and period of irrigation were set at one hour each.

NI = Not irrigated (rainfall only)

B. Fertilization Treatments:

Two fertlization methods were used: Conventional sidedressing (N_5 and N_6) and trickle fertilization with the irrigation water (N_1, N_2, N_3, and N_4). The initial source of N was from a commercial solution (Growers, 10-20-10) and subsequent applications were from calcium and potassium nitrates. For the N_1 - N_4 treatments, initial fertilizers were applied 8 days after transplant and subsequent weekly rates of fertilizer were divided into equal daily portions and applied with daily irrigation water. For the N_5 and N_6 treatments, initial fertilizers were applied 8 days after transplant and one subsequent side-dressing fertilization was carried out 25 days after transplant.

Fertilization Treatments

Nitrogen Treatments	Total Rates N	Total Rates P	Total Rates K	Initial N Application	Six Weekly N Applications Each of	Method of Application
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	
N_1	100.8	123.2	151.2	33.6	11.2	Liquid fertilizer through irrigation tube
N_2	67	123.2	151.2	33.6	5.6	"
N_3	84	123.2	151.2	16.8	11.2	"
N_4	50.4	61.6	106.4	16.8	5.6	"
N_5	100.8	123.2	151.2	33.6/67.2	--	Conventional fertilizer banded twice
N_6	67.2	123.2	151.2	16.8/50.4	--	"

Measurements (1976 and 1977):

a) Soil:

1. Soil water (tensiometers in each row, measured daily at 15-cm depth).

b) Plants:

1. Population.
2. Plant Heights (weekly).
3. Leaf Area and number of Leaves (monthly).
4. Root Distribution Profile.
5. Yield and Quality.
6. Leaf Nutrient Content.

c) Weather Data & Irrigation Water:

1. Rainfall (daily).
2. Pan Evaporation (daily).
3. Irrigation Water Applied (daily).

Results and Discussion

The weather data collected was used to calculate the water deficit (80% of screened pan evaporation less rainfall) and the irrigation water requirements. Figure 1 shows the water deficit for 1976 and 1977. In 1976, a wet year, the calculations showed that there was an excess of water of about 8 cm, whereas, in 1977, a dry year, there was a water deficit of approximately 12 cm. Rainfall distribution was nearly adequate in 1976, but extremely poor in 1977, thus making the crop more dependent on irrigation.

Irrigation waters applied in 1976 and 1977 are shown cumulatively in Figure 2. In 1976, irrigation water was merely applied to distribute nutrients to the crop. In 1977, 12 cm of irrigation water was applied to make up the water deficit shown in Figure 1.

Average fertilizer-N application rates for 1976 and 1977 are shown in Figure 3. During wet periods (1976) additional fertilizer-N was added initially as recommended by Clemson University Extension; however, in this type of soil and with trickle irrigation systems, less fertilizer-N can be applied initially because the grower can use the system to make up any deficiencies during the growing season. Particularly, in cases where excess rainfall could potentially cause tobacco "flopping," the grower has the capability of adding NO_3-N even during rainfall.

Plant heights measured weekly during 1976 and 1977 were averaged for all trickle irrigated and non-irrigated treatments and are shown in Figure 4. In 1976, excessive rainfall cancelled out irrigation effects, but early in the 1977 season, repeated short droughts made a maximum 19 cm difference in plant height 52 days after transplanting. However, when rainfall started 90 days after transplanting, the non-irrigated tobacco started growing again at a high rate and eventually matured about 20 days later than the irrigated tobacco. Commercially, this late maturity causes great scheduling problems with curing barns because the growers have only a fixed time to get their tobacco to the auction. If they miss their local market, they must transport their crop to other auctions often located many miles from their farm.

Dry matter of tobacco roots from trickle irrigated versus non-irrigated treatments (Figures 5 and 6) and from two fertility treatments (N_2 in Figure 7 and N_3 in Figure 8) demonstrate the effect of irrigation and fertilization on root distribution and total weight in 1976. Similar effects were noted in 1977, although with proportionally greater weights. Trickle irrigation alone almost doubled the root weight throughout the soil profile. Fertilization through the trickle system at the N_2 level increased the amount of roots in the top 15 cm, but did not increase the total weight of roots when compared with the M_1N_1 treatment.

The tobacco leaf area before topping, as influenced by trickle irrigation and N-fertilization is presented in Table 1 for 1976 and 1977. In 1976, irrigation did not affect leaf area significantly, but N-fertilization at 1/2 the conventional rate through the trickle irrigation system resulted in a significant decrease in leaf area of 3685 cm^2. In 1977, a relatively dry year, all irrigated treatments produced significantly greater leaf areas than the non-irrigated treatments. Specifically, in treatments fertilized at the same level (i.e. NI-N_5 - TI-N_1 and NI-N_6 - TI-N_2) the increased leaf areas were 3582 (significant) and 689 (nonsignificant) cm^2, respectively.

Tobacco yield, mean USDA support price and mean gross income for 1976 and 1977 are shown in Tables 2 and 3. In 1976, only the tobacco from the M_1N_2 treatment produced a significant yield increase over the non-irrigated treatment (255 kg/ha). The other treatments produced yields comparable to the maximum yield of 1900 kg/ha predicted for this soil by SCS. Since the mean support price is based on quality and was not reflected by the various treatments (range: 2.53 to 2.55 $/kg), the mean gross income reflected differences proportionally equivalent to that of yield. Mean gross income ranged from a low of 4613 $/ha to a maximum of 5599 $/ha. In 1977, the final yield results showed no difference between treatments. Yield data by harvest (data not shown) indicated that the trickle irrigated tobacco matured 2-3 weeks earlier than the non-irrigated tobacco. These differences in maturity rate were reflected by significant quality improvement as reflected by the USDA mean support price which is based on quality. The mean support prices ranged from 2.27 $/kg (NI-$N_5$) to 2.57 $/kg (TI-$N_4$), and reflected a 12% increase in quality. The N_4 (50 kg/ha N) and N_2 (67 kg/ha N) N-fertility treatments reflected significant quality improvement over the high fertility rates N_1 (100 kg/ha N) and N_3 (84 kg/ha N). The mean gross income for 1977 ranged from 5911 $/ha (NI-$N_5$) to 7035 $/ha (TI-$N_2$) for a 19% income increase with 33 kg/ha less N-fertilizer applied.

Leaf chemical analyses were performed in 1976 and 1977 on random samples by harvest for each treatment; Tables 4 through 7 summarize the 1977 data for reducing sugar, total leaf N, Nicotine and Nornicotine (total alkaloid other than Nicotine). Excessive rainfall in 1976 overshadowed the treatment effects and are not presented here.

Reducing sugars (Table 4) of trickle irrigated tobacco leaves were nearly twice as large as those of non-irrigated tobacco. Reducing sugar content also increased proportionally with decreasing N-fertilization both for the irrigated and non-irrigated treatments. High reducing sugar content in tobacco leaves usually produces high quality smoking tobacco.

Total leaf Nitrogen contents (Table 5) were nearly constant throughout the season and were not affected by N-fertilizer treatments, possibly indicating that the low fertilizer rates were adequately supplying the Nitrogen needed by the Tobacco. However, irrigation generally decreased the leaf N content, possibly indicating that irrigation may have somewhat diluted the N pool in the soil. Usually low N content in tobacco leaves will result in better tasting tobacco.

Leaf Nicotine contents (Table 6) tended to be greater for the non-irrigated than for the irrigated tobacco, but generally was not affected by N-fertilization rates.

Leaf Nornicotine contents (Table 7) (total alkaloids other than Nicotine) were not affected by either irrigation or N-fertilization rates.

The leaf Nitrogen to Nicotine ratio (Table 8), an index of tobacco quality, is usually best when its value lies between 0.7 and 0.8 and it should not be above 1.0. Tobacco harvested first (harvests 1 and 2) tends to have a ratio greater than desirable. However, by using lower N-fertilization rates (N_2 and N_4) the ratios obtained for the first two harvests for the N_4 were 0.94 and 0.92 and that of the N_2 were 1.04 and 0.90 respectively. Generally, irrigation also lowered the ratio closer to 1.0 for the first two harvests (i.e. 1.06 and 0.86 for the averaged trickle irrigated tobacco versus 1.28 and 1.13 for the nonirrigated tobacco for harvests 1 and 2, respectively). Manipulation of the Nitrogen to Nicotine Ratio by adjustment of irrigation and N-fertilization through the trickle system seems to be possible and would result in a higher quality tobacco. This was also reflected by the mean support price of the TI-N_2 and TI-N_4 tobacco which were 2.51 and 2.57 $/kg, respectively and significantly greater than other support prices (Table 3).

Conclusion

Manipulation of water and fertilizer-N application rates via trickle irrigation can be used to improve the quality, taste and gross income of flue-cured tobacco grown on deep sandy soils. Irrigation also greatly increased the reducing sugar content of tobacco. Because there is about 100,000 ha of Lakeland sand in the southeast, the management of this often-ignored soil for tobacco planting can be advantageous to farmers practicing crop rotation. The ability of precisely controlling water and nutrient application rates with trickle irrigation also provides new potential utilization of tobacco crop for protein production. Young tobacco leaves provide a great source of pure crystalline protein which could yield up to four times the protein produced by soybeans on similar acreage.

Acknowledgements

The authors acknowledge and express their appreciation to Mr. C.R. Cribb and family for providing the land, equipment and labor to manage the tobacco crop, to E. I. Du Pont de Nemours for providing the research grant which enabled the research to be conducted, to R.J. Reynolds Tobacco Co., and Philip Morris Co., for the careful chemical analysis of the leaf materials, to Mr. J.E. Ragsdale for the coordination of sample analyses, and to the support staff at the Coastal Plains Soil and Water Conservation Research Center for the day-to-day operation of the experimental site.

Table 1. The Influence of Trickle Irrigation and N-Fertilization on Tobacco Leaf Area.

LEAF AREA
(Tobacco - 1976-1977)

Treatments	N	6/30/76	Treatments	N	6/28/77	Remarks
	kg/ha	(cm^2)		kg/ha	(cm^2)	
M_4N_1	134	10330a+	NI-N_5	100	9,912 c	Non-
			NI-N_6	67	10,356 bc	Irrigated
M_1N_2	134	11545a	TI-N_1	100	13,494a	Trickle
M_1N_3	112	7860 b	TI-N_2	67	11,045ab	Irrigated/
			TI-N_3	84	13,607a	Fertilized
			TI-N_4	50	12,892a	

+ Column means followed by the same letter are not significantly different at the 5% confidence level.

Table 2. The Influence on Trickle Irrigation and N-Fertilization on Tobacco Yield, Support Price and Mean Gross Income for 1976.

TOBACCO YIELDS
(1976)

Treatments	Nitrogen Rate kg/ha	Total Yield kg/ha	Mean Support Price $/kg	Mean Gross Income $/ha
M_1N_1	134	2088ab*	2.53	5283ab
M_2N_1	134	1823 b	2.53	4613 b
M_3N_1	134	1977ab	2.55	5041ab
M_4N_1	134	1941 b	2.55	4949 b
M_1N_2	134	2196a	2.55	5599a
M_1N_3	112	1834 b	2.53	4641 b

+ Gross income calculated based on USDA grade and the 1976 averaged price index.

* Column means followed by the same letter are not significantly different at the 5% confidence level.

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Table 3. The Influence on Trickle Irrigation and N-Fertilization on Tobacco Yield, Support Price and Mean Gross Income for 1977.

TOBACCO YIELDS
(1977)

Treatments	Nitrogen Rate kg/ha	Total Yield kg/ha	Mean Support Price $/kg	Mean Gross Income $/ha
$TI-N_1$	100	2566	2.49a*	6422ab
$TI-N_2$	67	2801	2.51ab	7035a
$TI-N_3$	84	2742	2.49a	6820a
$TI-N_4$	50	2512	2.57 b	6474ab
$NI-N_5$	100	2594	2.27 c	5911 b
$NI-N_6$	67	2611	2.29 c	5980 b

+ Mean gross income based on 1977 USDA Annual Tobacco Support Price

* Column values followed by the same letter are not significantly different at the 95% confidence level.

Table 4. The Influence of Trickle Irrigation and N-Fertilization on the Reducing Sugar Content of Tobacco Leaves in 1977.

REDUCING SUGAR IN LEAVES

Treatments	Nitrogen Rate kg/ha	HARVEST 1 6/28/77	HARVEST 2 7/11/77	HARVEST 3 8/16/77	HARVEST 4 8/30/77	MEAN ALL HARVESTS
		%				
$TI-N_1$	100	12.75ab[+]	9.65ab	13.40ab	-	11.93
$TI-N_2$	67	13.55ab	12.23a	16.00a	-	13.93
$TI-N_3$	84	8.15 bc	13.30a	16.03a	-	12.49
$TI-N_4$	50	15.55a	15.65a	16.55a	-	15.92
$NI-N_5$	100	4.48 c	2.68 c	9.08 b	10.75	6.75
$NI-N_6$	67	5.73 c	5.40 bc	9.28 b	7.90	7.08
MEAN TI		12.50	12.71	15.50	-	13.57
MEAN NI		5.11	4.04	9.18	9.33	6.92
OVERALL MEAN		10.04	9.82	13.39	9.33	10.65

+ Column values followed by the same letter are not significantly different at the 95% confidence level.

Table 5. The Influence of Trickle Irrigation and N-Fertilization on the Total Leaf Nitrogen Content of Tobacco Leaves in 1977.

TOTAL LEAF NITROGEN

Treatments	Nitrogen Rate kg/ha	HARVEST 1 6/28/77	HARVEST 2 7/11/77	HARVEST 3 8/16/77	HARVEST 4 8/30/77	MEAN ALL HARVESTS
		%				
TI-N_1	100	1.81 bcd+	2.48 bc	2.32ab	-	2.20
TI-N_2	67	1.73 b d	2.48 bc	2.14 b	-	2.12
TI-N_3	84	2.38abc	2.16 b	2.01 b	-	2.18
TI-N_4	50	1.55 d	2.00 bc	2.00 b	-	1.85
NI-N_5	100	2.73abc	3.17a	2.54a	2.64	2.77
NI-N_6	67	2.37abc	2.98a c	2.63a	2.72	2.68
MEAN TI		1.87	2.28	2.12	-	2.09
MEAN NI		2.55	3.08	2.59	2.68	2.68
OVERALL MEAN		2.10	2.55	2.27	2.68	2.40

+ Column values followed by the same letter are not significantly different at the 95% confidence level.

Table 6. The Influence of Trickle Irrigation and N-Fertilization on the Leaf Nicotine Content of Tobacco Leaves in 1977

LEAF NICOTINE

Treatments	Nitrogen Rate kg/ha	HARVEST 1 6/28/77	HARVEST 2 7/11/77	HARVEST 3 8/16/77	HARVEST 4 8/30/77	MEAN ALL HARVESTS
		%				
TI-N_1	100	1.77a+	3.23a	3.86a	-	2.95
TI-N_2	67	1.66a	2.81ab	3.33	-	2.60
TI-N_3	84	1.91a	2.60ab	2.86	-	2.46
TI-N_4	50	1.67a	2.19 b	3.55a	-	2.47
NI-N_5	100	2.04a	3.02ab	3.99a	4.18	3.31
NI-N_6	67	2.05a	3.13ab	4.74a	4.71	3.66
MEAN TI		1.75	2.71	3.40	-	2.62
MEAN NI		2.05	3.08	4.37	4.45	3.49
OVERALL MEAN		1.85	2.83	3.72	4.45	2.91

+ Column values followed by the same letter are not significantly different at the 95% confidence level.

Table 7. The Influence of Trickle Irrigation and N-Fertilization on the Nornicotine Content of Tobacco Leaves in 1977

NORNICOTINE
(Total alkaloid other than Nicotine)

Treatments	Nitrogen Rate kg/ha	HARVEST 1 6/28/77	HARVEST 2 7/11/77	HARVEST 3 8/16/77	HARVEST 4 8/30/77	MEAN ALL HARVESTS
		%				
TI-N_1	100	0.10a+	0.17a	0.22a	-	0.16
TI-N_2	67	0.13a	0.14a	0.20a	-	0.16
TI-N_3	84	0.12a	0.13a	0.16a	-	0.14
TI-N_4	50	0.12a	0.12a	0.17a	-	0.14
NI-N_5	100	0.12a	0.15a	0.19a	0.22	0.17
NI-N_6	67	0.11a	0.12a	0.16a	0.24	0.16
MEAN TI		0.12	0.14	0.19	-	0.15
MEAN NI		0.12	0.14	0.19	4.45	0.15
OVERALL MEAN		0.12	0.14	0.18	0.23	0.17

+ Column values followed by the same letter are not significantly different at the 95% confidence level.

Table 8. The Influence of Trickle Irrigation and N-Fertilization on the Nitrogen to Nicotine Ratio of Tobacco Leaves in 1977.

LEAF NITROGEN TO NICOTINE RATIO

Treatments	Nitrogen Rate kg/ha	HARVEST 1 6/28/77	HARVEST 2 7/11/77	HARVEST 3 8/16/77	HARVEST 4 8/30/77	MEAN ALL HARVESTS
		%				
TI-N_1	100	1.02 bc[+]	0.78a	0.61a	-	0.80
TI-N_2	67	1.04 bc	0.90a	0.65a	-	0.86
TI-N_3	84	1.22ab	0.84a	0.77a	-	0.94
TI-N_4	50	0.94 c	0.92a	0.58a	-	0.81
NI-N_5	100	1.34a	1.10a	0.64a	0.63	0.93
NI-N_6	67	1.21ab	1.06a	0.57a	0.58	0.86
MEAN TI		1.06	0.86	0.65	-	0.86
MEAN NI		1.28	1.13	0.61	0.61	0.91
OVERALL MEAN		1.13	0.93	0.64	0.61	0.83

[+] Column values followed by the same letter are not significantly different at the 95% confidence level.

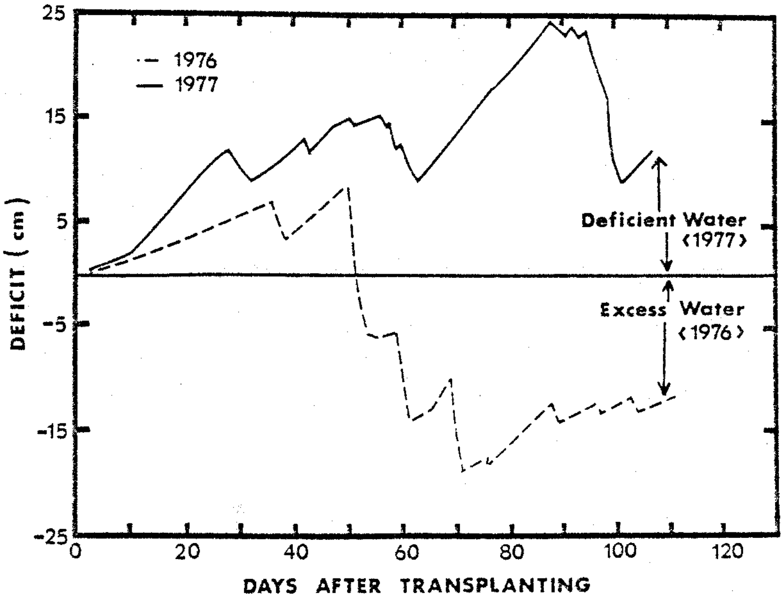

Figure 1. Water deficit (80% of pan evaporation less rainfall) for 1976 and 1977.

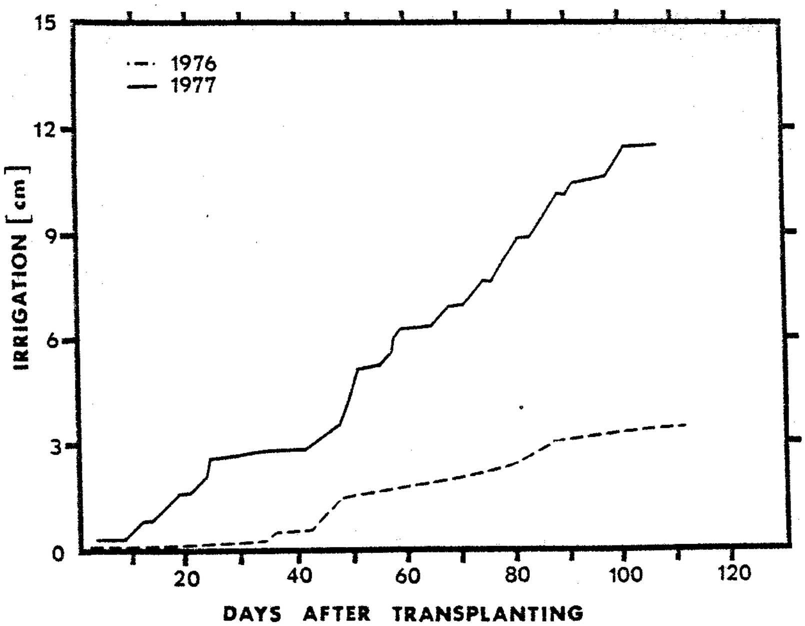

Figure 2. Irrigation water applied to tobacco in 1976 and 1977.

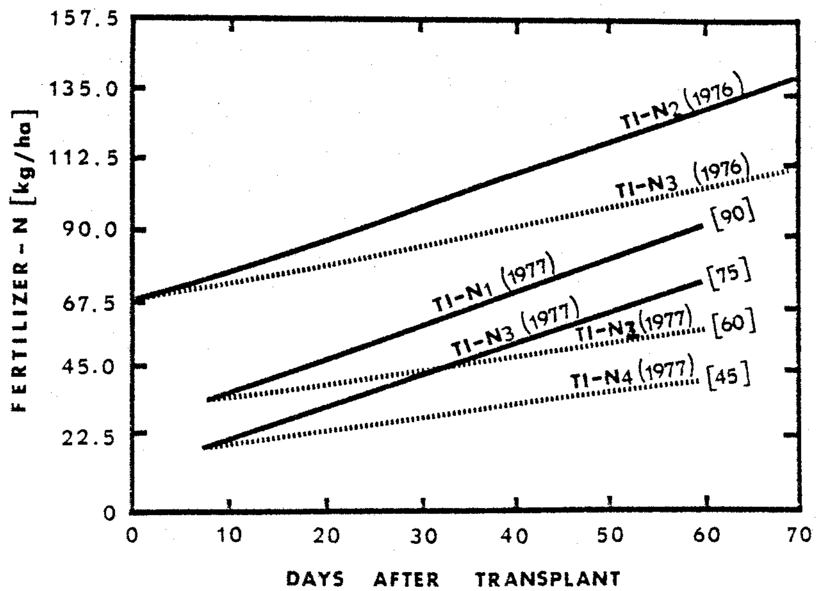

Figure 3. Fertilizer application rates for "trickle-fertilized" tobacco in 1976 and 1977.

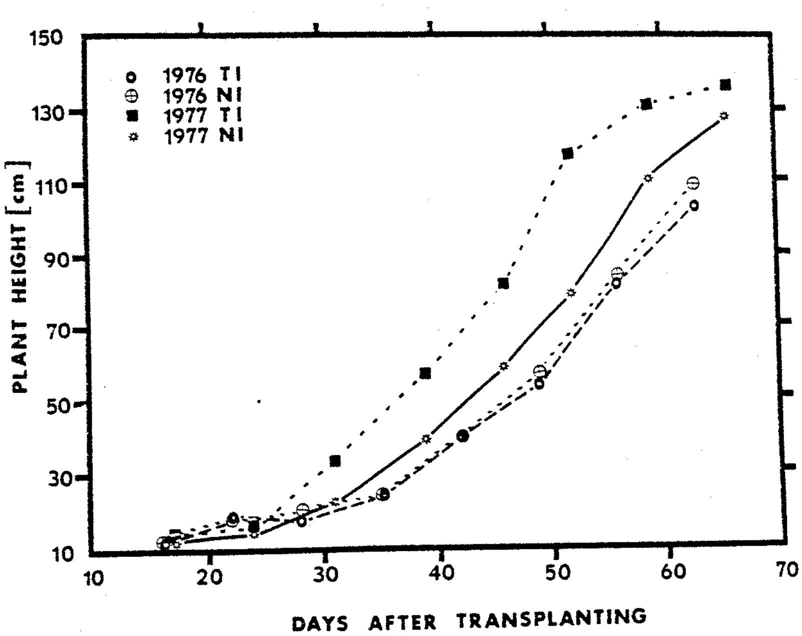

Figure 4. Tobacco plant heights as influenced by irrigation in 1976 and 1977.

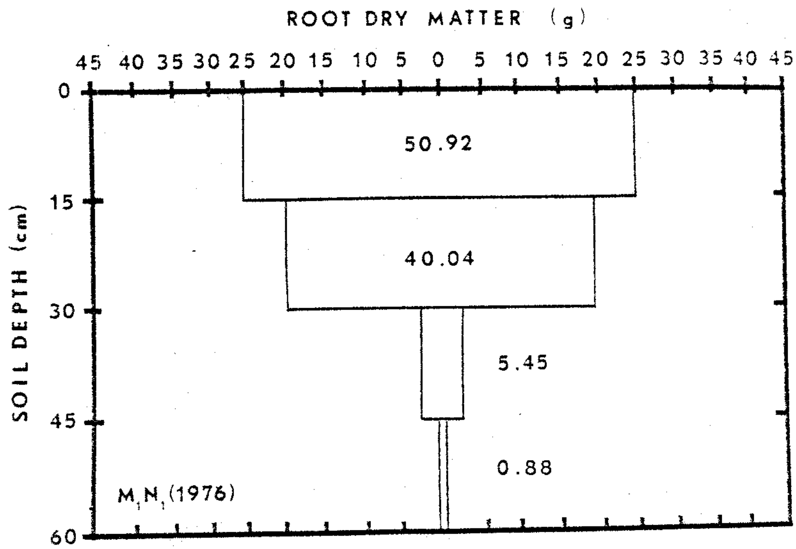

Figure 5. Dry matter of tobacco roots from a single trickle-irrigated plant.

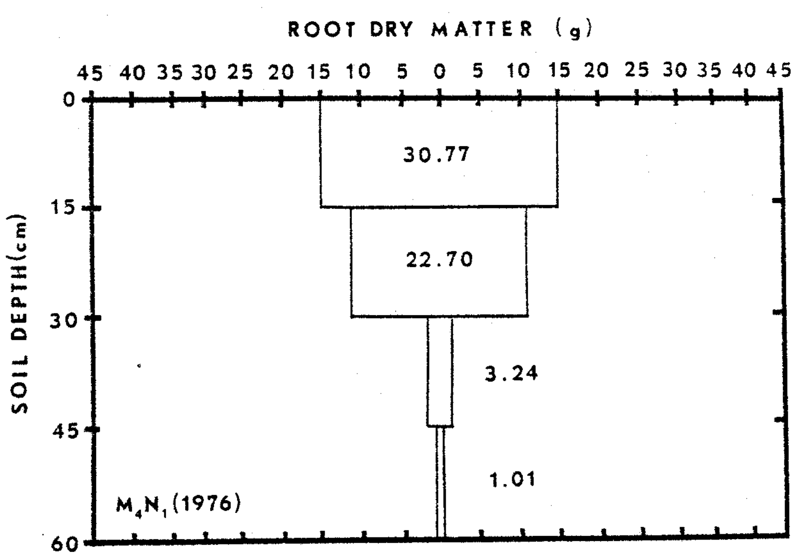

Figure 6. Dry matter of tobacco roots from a single non-irrigated plant.

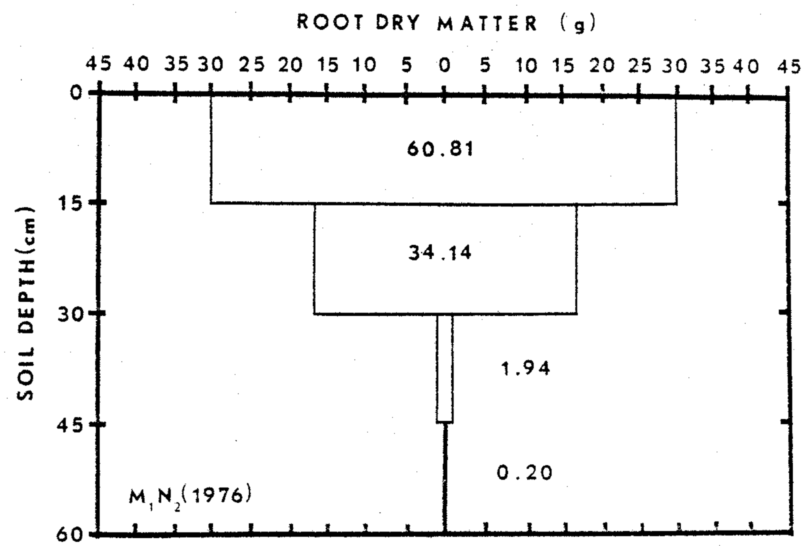

Figure 7. Dry matter of tobacco roots from a single trickle-irrigated and fertilized plant at 140 kg/ha of N.

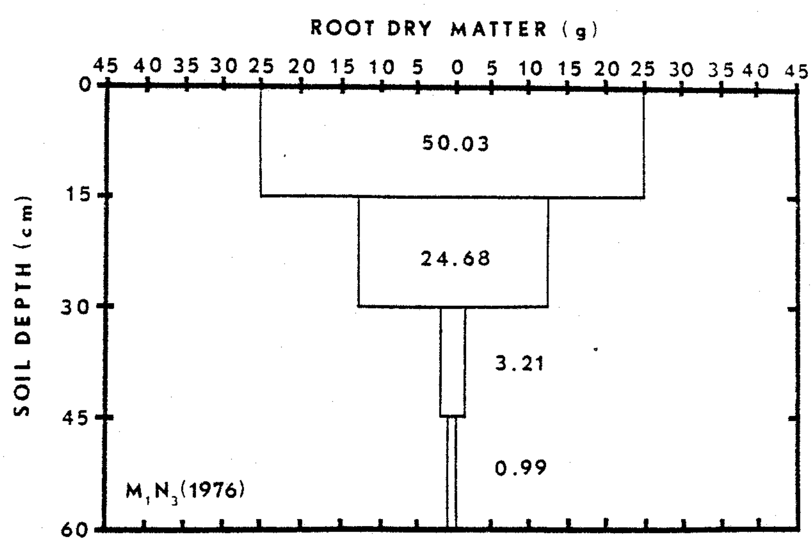

Figure 8. Dry matter of tobacco roots from a single trickle-irrigated plant fertilized at 112 kg/ha of N.