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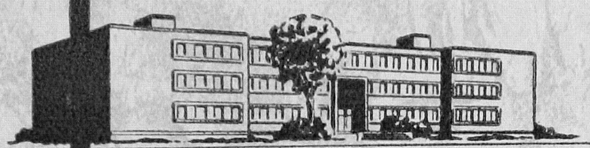

IRRIGATION OF FLUE-CURED TOBACCO IN NORTH CAROLINA

T. V. Wilson and C.H.M. van Bavel

Joint contribution from the Departments of Agricultural Engineering and Agronomy

DEPARTMENT OF AGRONOMY

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Contents

I. <u>Present status of research</u>

The North Carolina Agricultural Experiment Station initiated a formal program of research pertaining to irrigation of flue-cured tobacco in the spring of 1950. At the time of writing, the results of three years' work are available. These results are presented in this report, although more work needs to be done to round out the problem as a whole.

In the main, three questions have been given attention:

1. What is the desirable level of soil moisture for the tobacco plant, and what are the physiological consequences of not maintaining this level at all times? At first, an answer was sought from field experiments, but it became clear that it is very difficult to control and measure soil moisture levels with scientific precision in a field setup. Therefore, information on the water-relations of tobacco is now obtained from small bins or perhaps culture-vessels. Field experiments will continue to serve as means to verify ideas originating from controlled studies, and to study factors of management which interact with the irrigation practices.

2. Under field conditions, how can the moment be ascertained on which irrigation is to take place? This question is really one of measuring moisture stress. If the relation between stress and moisture content is known, it is a matter of measuring the moisture content. Stress vs. moisture content curves (moisture characteristics) have been determined for a few major North Carolina soils. More will be done in the future. Measuring soil moisture content by estimation has been shown rather satisfactory,* further work on checking this method being in progress.

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* van Bavel, C. H. M. and Wilson, T. V. Evapotranspiration estimates as criteria for determining time of irrigation. Agric. Eng. 33: 417-418. 1952.

3. How does the practice of irrigating tobacco enter into the analysis of the production costs? This question can only be answered with proper information of the effects of irrigation on yield and quality. The answer will show under what circumstances irrigation is of economic advantage, and, if so, how great the advantage is.

In the following, such answers as are available to the above questions and other results of interest are to be presented.

2. Experiments at McCullers Branch Station

a/ 1950 Season

A randomized block design was used in four replications. There were five treatments as follows:

A. All rain withheld from the plants for the first four weeks after the plants had become established.

B. Natural rainfall.

C. Heavy irrigation, keeping moisture stress below 300 cm water, and replenishing the surface 12 inches.

D. Light irrigation, keeping the moisture stress below 800 cm water and replenishing the surface 12 inches.

E. Light irrigation as in D, but replenishing only the top 6 inches.

As it turned out, treatment C received nine irrigations of 0.7 inches each, totalling 6.3 inches. Treatment D received four irrigations of 0.9 inches, totalling 3.6 inches and treatment E three irrigations of 0.5 inches, totalling 1.5 inches. During the growing period, the rainfall totalled 13.55 inches, just slightly below the average amount which is 14.80 inches. It is at once obvious, that the average amount of rain would not suffice for either treatment C or D, but on the other hand, that the amount required as a supplement is relatively small.

The soil of the plot was Ruston coarse sandy loam and the root zone estimated as 8 inches deep. From the moisture characteristic, the amount of irrigation water was computed (compare footnote on page 1). In view of the practice of hilling tobacco the correct estimation of the root zone is difficult. Extensive investigation showed that the experimental area was essentially homogeneous in regard to its moisture characteristic. The plots were approximately 29 x 32 feet in size and were irrigated with a quarter-circumference sprinkler on each plot corner. Without vegetation the sprinklers gave, upon test, a satisfactory, uniform distribution. As the tobacco grew taller, the center of the plots tended to receive less water than the sides. Leaks at the joints and the irregular lay of the land caused additional departures from the desired uniformity, so that one may say that the degree of achievement in establishing the various treatment was only fair and below the desirable.

The variety was Dixie Bright 101, fertilized in a double band with 900 pounds of 4-8-12 per acre. The stand was 3 1/2' x 22" (6800/acre). A good stand of plants was achieved in this experiment.

Each plot was provided with four Colman elements at 6" depth and one at 12" depth to record the soil moisture content by biweekly readings. The elements were buried 4" from a plant in the row. The elements were calibrated in the laboratory for the conversion of electrical resistance into soil moisture content. The result of the tremendous labor of calibration, frequent readings, and ensuing calculations was extremely disappointing. Several elements broke down while in the field. The agreement between the four replicates in one plot was so poor when the soil started to dry after an irrigation or a rain, that the results are practically meaningless for quantitative information. Moreover, it was later found that the calibration curves could not be reproduced with any great accuracy.

In the irrigated plots there were also employed tensiometers, two in each plot. These gave much better agreement, rapid response, and unequivocal readings. Nevertheless, there exists a problem of maintenance of the instruments and danger of fracture. Owing to the latter factors, the record from the tensiometers is far from complete.

Using all available information the following values were obtained for the average stress at 6 inches depth during the growing season of the crop.

Treatment A	1692 cm water
Treatment B	1389 cm water
Treatment C	288 cm water
Treatment D	123 cm water
Treatment E	321 cm water

Irrigation was applied when indicated by the tensiometers. Sometimes, of course, it was not possible to apply irrigation immediately, but usually the deviation was not more than one day.

The tobacco plants were cultivated, topped, suckered, harvested and cured in the conventional manner. The yield data were as follows:

Table I. Yield and value, 1950 McCullers crop.

	Yield	Value per 100#*
Treatment A	1462#/A	$ 25.29
Treatment B	1878#/A	$ 25.61
Treatment C	1730#/A	$ 25.81
Treatment D	1977#/A	$ 25.75
Treatment E	1956#/A	$ 26.80

* Prices based on average price received at the markets in 1939-1941.

The least significant difference at the 5% level was 200#/A for the yield data. No appreciable gain in yield, therefore, was found comparing the irrigated treatments (C, D, and E) with the unirrigated one (B). But a serious depression of yield resulted from the artificial drought in treatment A. It is also apparent that the value per 100# was unaffected. In this regard, it must be remarked that the system of curing and grading employed tended to equalize quality differences. Tobacco of all plots was cured together with tobacco of many other experiments. In this way, it is not possible to treat the tobacco of each plot to its individual requirements. This should, however, be done in an irrigation experiment.

Although fairly inconclusive, the experiment of 1950 was considered encouraging and indicative of the fact that when stresses of soil moisture exceeded the 800 cm level frequently, yield was depressed. No indication was given that the critical stress level was below 800 cm.

Chemical analysis of the cured leaves gave the following data:

Table 2. Chemical composition of 1950 McCullers crop

Treatment	Sugars	Nicotine	Total N	K_2O	Burn Test
A	13.57	1.24	2.17	2.91	1.17
B	15.71	1.44	2.02	2.65	1.20
C	19.29	1.06	1.74	2.68	1.25
D	17.47	1.17	1.92	2.78	1.22
E	17.73	1.30	1.92	2.75	1.21
LSD 5%	2.59	.27	.24	.49	.07

These chemical analyses, particularly the figures for sugars and total N, show that a difference in value would have been brought out with proper handling. The nicotine and nitrogen content, as a whole, was quite low, indicating a nitrogen or calcium deficiency.

b/ 1951 Season

The experiment was repeated in 1951 at the McCullers Branch Station at the same site. Plots were larger than in 1950, namely 31 1/2 x 40 feet. The treatments were (randomized block design in four replications):

A. Heavy irrigation - maximum tension 100 cm.

B. Light irrigation - maximum tension 800 cm.

C. "Rule of thumb" - 1 1/2" per week in irrigation or rain.

D. Artificial drought during July.

E. Natural rainfall.

The plots were instrumented with tensiometers and Colman blocks as in 1950. The experience with the Colman blocks were equally disappointing as in 1950.

The treatment D became a partial failure when a four-inch rainstorm caused the covers to fall on the plants and caused considerable damage.

In all other respects the experiment was similar to that of 1950. Unfavorable weather during the transplanting time and poor plant material caused very irregular stand. One replication was especially poor and was, therefore, disregarded in the further analysis.

In 1951 the weather at McCullers was decidedly droughty, especially during the month of June. Total rainfall from May 15 until August 15 was 11.81 inches compared with an average of 14.39 inches. Treatment A received 17 irrigations of .63 inch, treatment B 8 irrigations of 1.10 inch and treatment C received irrigation in varying amount on six occasions totalling to 7.00 inches.

Using the information from tensiometers and Colman blocks, the following figures resulted indicating the average moisture stress during the growing season:

Treatment	Av. stress in cm water
A	164
B	264
C	327
D	1337
E	1416

These values are statistically different except D and E (for reason, see above).

Yield data based on 3 replications are as follows:

Table 3. Yield, value, and total value of 1951 McCullers crop.

Treatment	Yield - #/A	Value - $/A	Value $/100#
A	1604	293	18.29
B	1538	265	17.25
C	1622	286	17.69
D	1151	157	13.56
E	1335	234	17.60
LSD - 5%	198	50	2.12

The experiment appears not capable of differentiating the three irrigation treatments. The L.S.D. value is quite high, as result of the inevitable inaccuracies discussed under the 1950 experiment. Differences in quality are not present at all. This fact was also discussed previously, as to its probable cause. The low value for treatment D in both yield and quality was probably in part caused by the damage cited above.

No chemical analyses were made of the crop. Studies were made of the rate of growth of the plants. They are summarized in the Figures 1 and 2. Treatments A, B, and C are represented by a single curve, as are D and E. The belated and irregular development of the plants that were not continually provided with an adequate water supply is at once obvious. The length measurements were done on approximately 60 plants per plot and are quite reliable when averaged for drawing the Figures 1 and 2.

The growth measurements also gave rise to another observation in conjunction with the measurements of soil moisture stress. For three or four-day periods, the stress was determined in all plots with treatments A, B, and C.

Also the growth rate in centimeters per day was determined for the same plots. In each week the stress values ranged from 50 to approximately 800 cm water and the weekly correlation between stress and growth rate was determined.

Stress values below 800 cm were not correlated with growth rate, although a tendency for negative values existed. Negative values indicate less growth with higher stress as is to be expected. This observation is in concurrence with the yield data, which show absence of response to moisture regimes below 800 cm tension.

c/ 1952 Experiment

In 1952 a similar experiment was conducted on the same area. Owing to continued cropping with tobacco the area was in bad shape, deficiencies occurred and yields were very low, averaging less than 1000 pounds. The experiment was, therefore, a failure and inconclusive.

3. Experiments at the Oxford Branch Station

a/ 1951 Season

The experiment was located on Enon sandy loam at the same site as the old lime - fertilizer experiment. It consisted of 48 plots 20 x 80 feet organized as follows:

Replications: 4

Main plots: 2 limed (up until 1928)
not limed

Subplots: 3 (A) irrigated at 300 cm tension
(B) irrigated at 800 cm tension
(C) no irrigation

Sub subplots: 2 regular fertilizer rate (1200# 3-9-6)
high fertilizer rate (1600# 3-9-6)

The lime treatment was an inherent feature of the experimental site. The

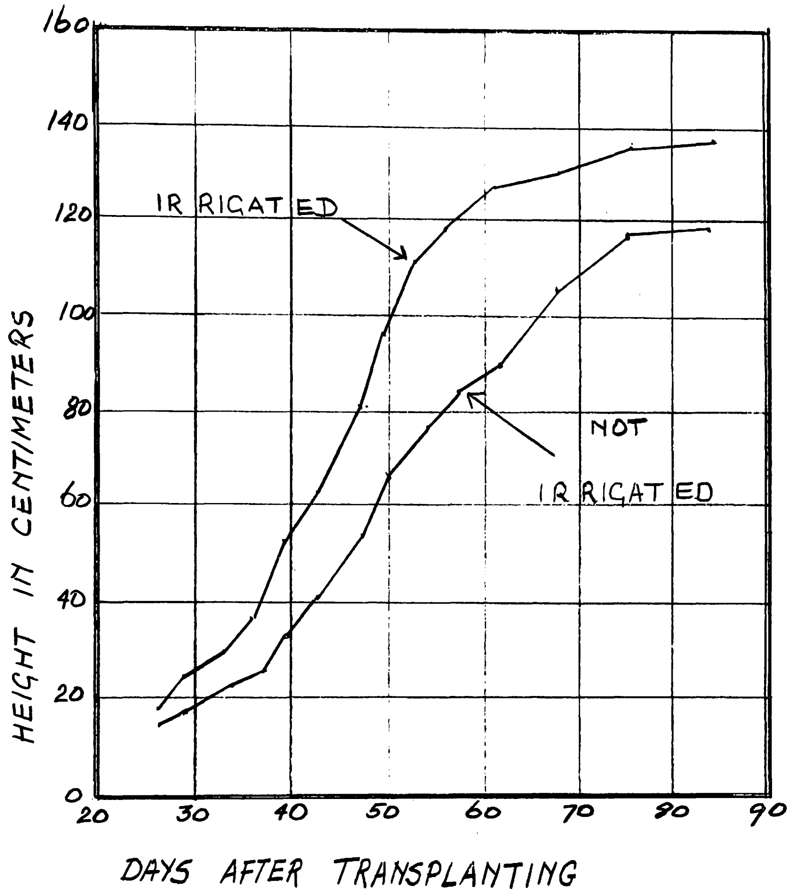

Figure I. Length of tobacco plants - irrigated vs. unirrigated

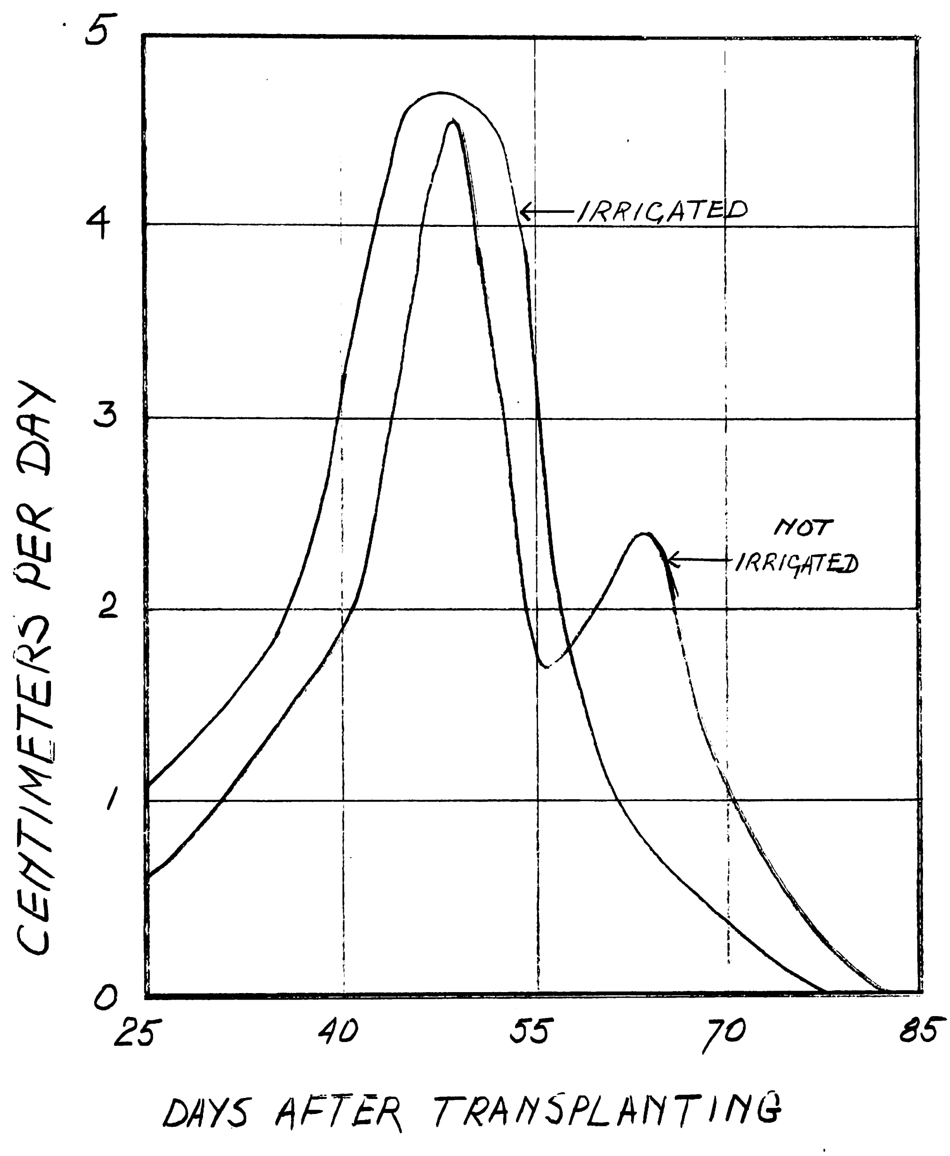

Figure 2. Growth rate of tobacco plants - irrigated vs. unirrigated

additional amount of fertilizer over the regular rate was applied as a side-dressing. The variety grown was Oxford 26 and the normal cultural practices followed. Since the experiment was relatively large, the tobacco from the irrigated and unirrigated sections could be cured individually so as to better bring out the influence of irrigation on quality.

In regard to the irrigation treatment the following is to be noted. Since suitable accuracy appeared possible (see footnote on page 1) with an estimation method for determining the moisture content of the soil and the proper time for irrigation, it was used instead of instruments.

This system resulted in the 1951 season in 10 irrigations of approximately 1.0 inches for treatment A, totalling 8.2 inches. In treatment B, 4 irrigations were applied, totalling 4.6 inches. Total rainfall from May 15-August 15 was 11.65 inches, compared with an average of 14.30 inches.

The resultant average tensions were as follows:

Table 4. Moisture tension in 1951 Oxford experiment.

	0-3 wks.	3-10 wks.	10-15 wks.	Whole period
Treatment A	70	94	170	100
Treatment B	101	280	324	242
Treatment C	186	2078	1249	1470

In regard to yield in pounds/acre, irrigation and fertilizer rate gave significant effects, but not the lime treatment. A significant interaction between fertilizer rate and lime treatment occurred.

Table 5. Yield of 1951 Oxford crop.

	pounds/acre
Irrigation treatment A	1649
Irrigation treatment B	1622
Irrigation treatment C	1334
Regular fertilizer rate	1487
High fertilizer rate	1583
No lime - regular fertilizer	1433
Lime - regular fertilizer	1541
No lime - high fertilizer	1565
Lime - high fertilizer	1601

With reference to value per 100 pounds (1939-1941 average) there was a significant effect of liming, irrigation, and fertilizer rate, as well as an interaction of liming and irrigation.

Table 6. Value per 100 pounds of 1951 Oxford crop.

	$/100 pounds
Lime	20.27
No lime	23.28
Irrigation treatment A	23.74
Irrigation treatment B	23.21
Irrigation treatment C	18.35
Regular fertilizer rate	22.41
High fertilizer rate	21.13
No lime - Irrigation A	24.94
Lime - Irrigation A	22.55
No lime - Irrigation B	23.70
Lime - Irrigation B	22.71
No lime - Irrigation C	21.16
Lime - Irrigation C	15.53

Combining yield and value in value per acre in dollars significant effects resulted of irrigation only, not of either liming or fertilizer rate. However, there were interactions of liming and irrigation and of liming and fertilizer rate.

Table 7. Total Value of 1951 Oxford crop.

	$/Acre
Irrigation treatment A	383
Irrigation treatment B	370
Irrigation treatment C	235
No lime - Irrigation A	391
Lime - Irrigation A	375
No lime - Irrigation B	367
Lime - Irrigation B	372
No lime - Irrigation C	275
Lime - Irrigation C	194
No lime - regular fertilizer	335
Lime - regular fertilizer	313
No lime - high fertilizer	354
Lime - high fertilizer	306

The implications of the figures presented are rather plain. The irrigation treatments A and B amounted to approximately the same soil tension but were both considerably different from treatment C. This is expressed in yield, value and value per acre in a forceful manner.

The added fertilizer increased yields some, particularly where no lime had been applied. However, both lime and added fertilizer decreased quality, especially when combined. Irrigation markedly increased quality. Combination of yield and quality into the value per acre shows a very marked increase as result of irrigation. Other effects, previously noted, more or less counterbalance each other. One important interaction remains, however, that of irrigation and lime. It shows that with irrigation, the liming practice does not depress the per acre value, whereas it does so appreciably without irrigation. This finding has considerable practical consequence.

The effects noted above on quality merited further investigation and detailed chemical analyses of the leaves were made. Determined were: total N, nicotine, sugars, burn test, K_2O, CaO, MgO and P_2O_5.

In regard to total N, the following significant effects were noted:

Table 8. Total N in 1951 Oxford Crop.

Irrigation treatment A	1.65
Irrigation treatment B	1.67
Irrigation treatment C (no irrigation)	2.40
Regular fertilizer	1.83
High fertilizer	1.98

Nicotine showed as significant effects:

Table 9. Nicotine in 1951 Oxford crop.

No lime	2.47
Lime	2.78
Irrigation treatment A	1.76
Irrigation treatment B	2.10
Irrigation treatment C (no irrigation)	4.02
Regular fertilizer	2.50
High fertilizer	2.75
No lime - Irrigation A	1.75
Lime - Irrigation A	1.80
No lime - Irrigation B	1.93
Lime - Irrigation B	2.27
No lime - Irrigation C (no irrigation)	3.76
Lime - Irrigation C (no irrigation)	4.28

The lime - irrigation interaction is especially interesting and substantiates what was said before about the quality.

The trend in sugar content was exactly opposite to that of total N:

Table 10. Total sugars in 1951 Oxford crop

Irrigation treatment A	21.18
Irrigation treatment B	22.56
Irrigation treatment C	14.85
Regular fertilizer	20.47
High fertilizer	18.59

The burn test showed only a significant effect owing to irrigation

Irrigation treatment A	1.47
Irrigation treatment B	1.40
Irrigation treatment C	1.25

The P_2O_5 content was lower without liming and without added fertilizer, but the difference in both cases was inconsequential. No influence of irrigation could be detected. The remaining constituents are given, omitting not-significant effects.

Table 11. K_2O, CaO, and MgO content of 1951 Oxford crop.

K_2O	
Irrigation treatment A	2.15
Irrigation treatment B	1.82
Irrigation treatment C	1.97
Regular fertilizer	1.80
High fertilizer	2.16
Irrigation A - Regular fertilizer	1.88
Irrigation A - High fertilizer	2.43
Irrigation B - Regular fertilizer	1.69
Irrigation B - High fertilizer	1.95
Irrigation C - Regular fertilizer	1.84
Irrigation C - High fertilizer	2.10

CaO	
No lime	2.58
Lime	3.66
Irrigation treatment A	3.20
Irrigation treatment B	2.84
Irrigation treatment C	3.32
Regular fertilizer	3.02
High fertilizer	3.22
MgO	
No lime	.60
Lime	.86
Irrigation treatment A	.92
Irrigation treatment B	.67
Irrigation treatment C	.80
No lime - regular fertilizer	.62
No lime - high fertilizer	.59
Lime - regular fertilizer	.82
Lime - high fertilizer	.89

The data on chemical analysis, particularly of the organic constituents, give reasonably good explanation of what was noted in regard to quality.

The 1951 experiment at Oxford showed a large benefit from irrigation. The weather was dry below average but not unusually so. Also the experiment pointed the way for more work on cultural practices that may look different when combined with irrigation.

b/ <u>1952 experiment</u>

The 1951 experiment at Oxford was repeated in 1952 on the same site, but an additional variable introduced, namely stand. Plots were again 20 x 80 feet and 48 in number. Layout was as follows:

Replications: 4

Main plots : 2 not limed vs. limed (until 1935)

Subplots : 3 (Aa) Irrigated at 800 cm tension and 10,500 plants per acre.

(Ab) Irrigated at 800 cm tension and 6800 plants per acre.

(Bb) Not irrigated and 6800 plants per acre.

Sub subplots: 2 Regular fertilizer rate: 900# (1540#) of 4-8-10

High fertilizer rate: 1200# (2040#) of 4-8-10

The fertilizer rates in parentheses go with the high rate of planting. All of the fertilizer was applied at one time before planting.

With 10,500 plants/A the spacing was 2' 9" between rows and 18" in the row. With 6800 plants there was 3' 6" between rows and 22" in the row. The variety used was Dixie Bright 101.

Although the early part of the season tended to be dry, natural rainfall was fairly ample in 1952. Compared with an average figure of 14.30 inches between May 15 and August 15, there was in 1952 16.26 inches in that same period and the distribution was somewhat erratic but not too unusual. The irrigated plots received five irrigations of 1.3 inches each. This goes to show, that even with higher than average rainfall, irrigation is needed in order to maintain suitable soil moisture conditions.

The yield data gave the following significant results.

Table 12. Yield of 1952 Oxford crop.

No lime	1543#/acre
Lime	1629#/acre
Irrigated x 10,500	1856#/acre
Irrigated x 6,800	1484#/acre
Not irrigated x 6,800	1418#/acre

The yield increase owing to irrigation is small, much smaller than in 1952, but still significant. Outstanding is, of course, the large response due to combining high stand and irrigation.

The value per 100# in dollars (based on 1952 season averages) gave the following significant results:

Irrigated x 10,500	$53.95
Irrigated x 6,800	$55.76
Not irrigated x 6,800	$52.46

The unirrigated tobacco had a definitely lower value than the irrigated tobacco. Again the difference was smaller than in 1951. The lowering of quality with the higher stand was noticeable but not significant.

In total value in dollars per acre, only one comparison turned out significant:

Irrigated x 10,500	$1,001
Irrigated x 6,800	$ 826
Not irrigated x 6,800	$ 743

It is shown, therefore, that even in a not droughty year a worthwhile increase in monetary return may be secured. Particularly outstanding is the effect of combining irrigation with a high stand. This aspect will be more thoroughly pursued in the future, since the present experiment was not complete by not having the combination of high stand and absence of irrigation.

Predictions made in regard to this experiment that the gain in yield as result of high stand would be offset by depressed value, have certainly not come true.

The chemical analyses of the crop substantiates well the findings on value per 100 pounds. Unirrigated tobacco had definitely less desirable character. The high stand tended to be in the same direction.

Table 13. Chemical composition 1952 Oxford crop.

Only significant effects are given.

	Sugars	Nitrogen	Nicotine	K_2O
Irrigated x 10,500	22.09	2.31	1.92	3.22
Irrigated x 6,800	24.83	2.22	1.79	2.80
Not irrigated x 6,800	22.04	2.51	2.31	3.03
Not limed	24.58	2.25		
Limed	21.39	2.45		

4. Experiments under controlled conditions

In trying to ascertain more precisely the most desirable level of soil moisture stress an experiment was started in 1952 at Agronomy Field Headquarters in Raleigh. Dixie Bright 101 was grown in 4 x 4 feet concrete bins, four plants to a bin. Tensiometers were placed in the bins at 6 inches depth to measure moisture tension accurately. Rain was kept off with removable covers.

Eight weeks after transplanting, when the plants had attained full development, no more water was given to one-half of the plants. Nevertheless, they seemed to mature normally and gave a yield which was identical to that obtained from plants that were watered throughout the harvesting stage.

For the first eight weeks the following schedule was used.

Treatment A - irrigated at 200 cm tension

Treatment B - irrigated at 400 cm tension

Treatment C - irrigated at 800 cm tension

Low moisture stress was, therefore, maintained in all treatments. Growth rate, height, yield, and quality were measured. No difference was found between treatments, although a slight trend was indicated in favor of the low tension treatment (A).

This experiment suffered from many defects, resulting mostly from inexperience. Nevertheless, one may conclude at least that no benefit will likely be derived from irrigating before the 800 cm tension limit is arrived at.

5. Irrigation Methods and Layouts

Source of water

At both stations ponds containing disease-free water were available within 600 feet of the plot layouts. The watersheds in both instances were entirely on the Experiment Station Farm, eliminating the probabilities of spreading diseases through the irrigation water.

McCullers Experiment Station

Due to a shortage of funds in 1950 an old irrigation system comprising a piston type pump, light weight steel pipe, and revolving sprinklers was used. The pump, a surplus of World War I, driven by a 7 1/2 h.p. water cooled one-cylinder gasoline engine was rated at 80 gallons per minute at 80 p.s.i. pressure. The light weight steel pipe was equipped with quick couplings for portability, although there was considerable leaking at the joints because of old, hardened rubber gaskets for which replacements were not available. Four part-circle sprinklers, adjusted for quarter-circle operation, were used on each plot - one in each corner. Tests were run to determine the distribution and output of the sprinklers under various pressures. The most uniform distribution was obtained at 25 p.s.i. pressure; consequently, that pressure was used in irrigating the plots.

In 1951, to get away from the laborious job of preventing water from leaky joints from running into unirrigated plots, an underground layout of pipe lines was installed. Plot sizes were changed to 31.5' x 40' which permitted a 1 1/2" main line to be installed up the center of the plot area with 1/2" laterals for distribution. The layout is shown in Figure 3.

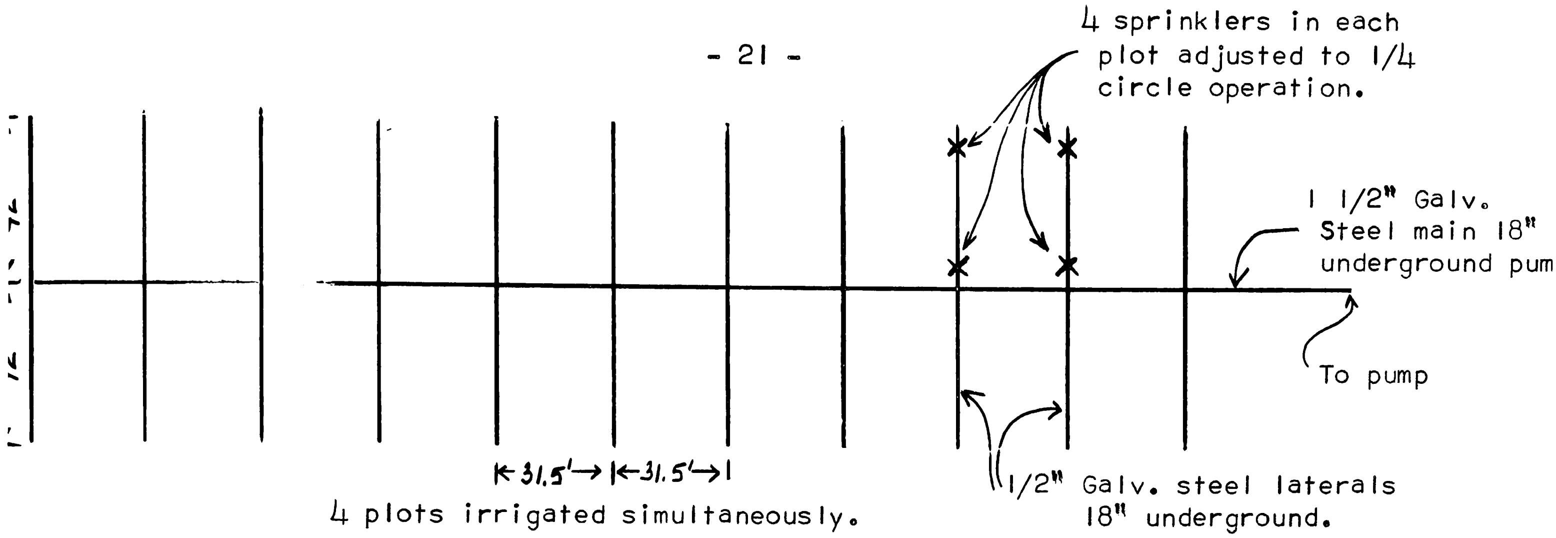

Figure 3A. Irrigation layout at McCullers - 1951 and 1952

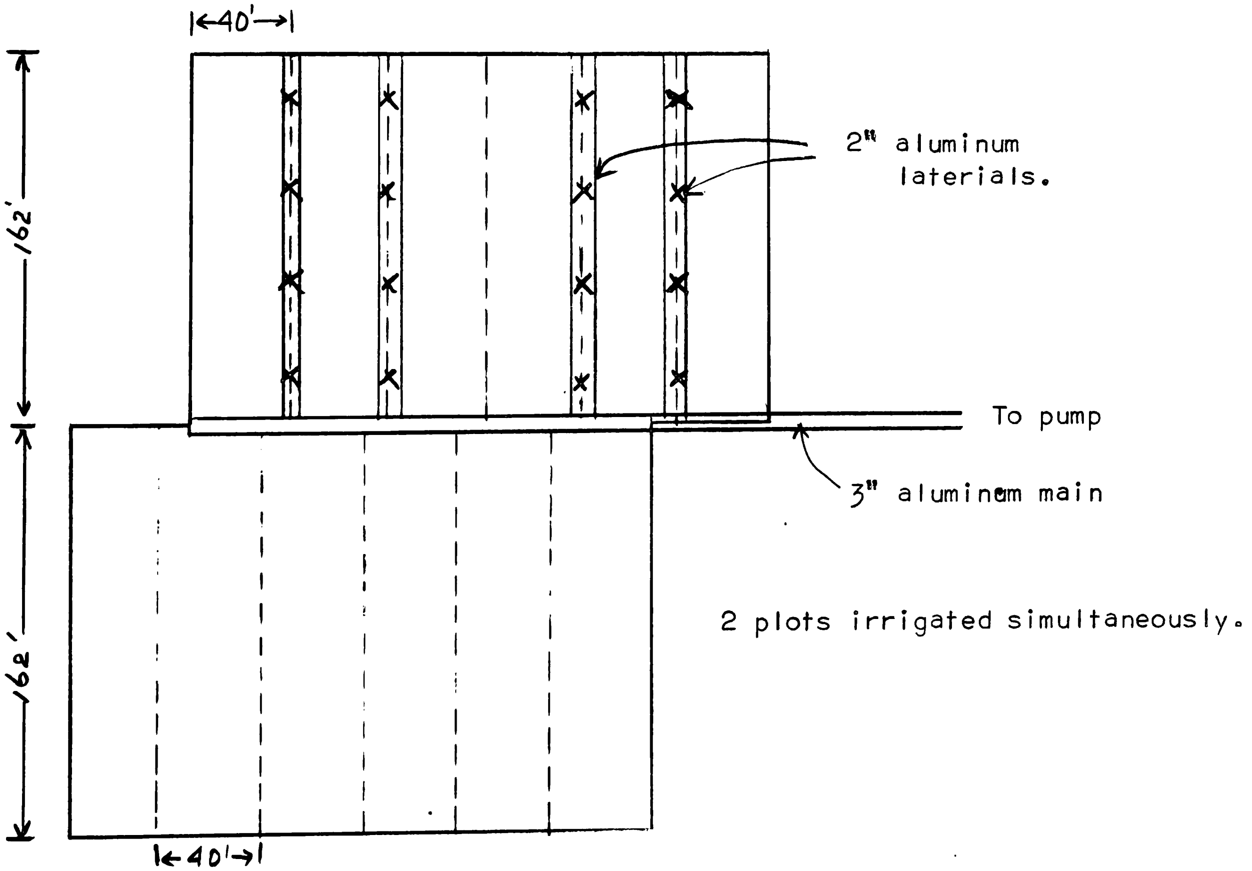

Figure 3B. Irrigation layout at Oxford - 1951 and 1952

The old, bulky positive displacement pump was abandoned in favor of a portable centrifugal pump powered by a 7 1/2 h.p. air cooled gasoline engine.* The distribution of water was still very good on a calm day; however, the wider spacing permitted a much more erratic distribution under windy conditions, and poorer distribution was obtained as plants grew due to drops striking the plants before reaching the end of their trajectory. That handicap was partially corrected by using nozzles which produced higher trajectories than were previously used (21° nozzles instead of 7° nozzles).

The same system was used in 1952.

Oxford Tobacco Station

A new portable irrigation system was available for the Oxford project.* It was made up of 3" and 2" aluminum pipe, a Gorman Rupp Model 6201 centrifugal pump mounted on wheels, and part-circle Skinner sprinklers. A diagram of the layout is shown on page 21.

Tests on the sprinklers indicated a satisfactory distribution of water over the plots under low or no wind conditions. Some trouble was encountered with leaky joints, particularly during the first few minutes of operation before pressure fully sealed the joints. Occasionally, sand or other foreign material also got in the joints, preventing a perfectly sealed joint.

During the latter part of the seasons after the last cultivation, there was a slight amount of runoff indicating that the rate of application was a little too fast. The rate was 0.51 inches per hour. As long as the soil was in a loose condition, however, the rate of infiltration exceeded the rate of application.

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* Loaned specifically for tobacco irrigation by the Gorman-Rupp Pump Company, Mansfield, Ohio.

* Loaned by Thompson Irrigation Company, Kinston, N. C.

6. Economics of Irrigation*

There are a number of different costs associated with irrigating any crop. Some of those costs are:

1. Making available a water supply.
2. The initial cost of an irrigation system.
3. Operation and upkeep costs.
4. Labor

The cost of a water supply will vary from one farm to another. On many tobacco farms there is already available a farm pond of sufficient capacity from which to irrigate sizable acreages. On other farms there are running streams which would provide sufficient water for irrigating large acreages. The cost of providing a water supply in such cases would be negligible. On the other hand, if special consideration had to be given to providing a water supply, the cost would vary according to the ease with which the supply could be made available. So many variations are encountered from farm to farm that it is practically impossible to set up a criterion on which to base the cost of providing ample supplies of water. The range of cost varies from zero in some cases to figures beyond economic reason in other cases.

The initial cost of an irrigation system is influenced by the following factors:

1. Size, shape, and arrangement of fields.
2. Distance between the source of water and the fields to be irrigated.
3. Size of system purchased when compared to size area to be irrigated.
4. Elevation difference between source of water and the field to be irrigated.

The initial cost of an irrigation system where relatively short distances from the water supply to the field are encountered, averages close to $100 per

* Grateful acknowledgement is made to W. H. Pierce of the Agricultural Economics Department, for help rendered in preparing this section.

acre. This is true for systems ranging upward from about 6 or 8 acres. Systems for smaller acreages cost more on a per acre basis. Three examples, showing the field layouts and bills of materials needed are shown in Figures 4, 5, and 6. The fields shown are approximately square; however, the cost would not vary much for different shaped fields unless they were very odd shaped. Under ideal conditions the cost could be reduced; under adverse conditions it would be increased considerably.

Using 1951 data obtained at the Oxford Station, the gross increase in the crop value as a result of 4.6 inches of irrigation was $337.50 per acre (about half due to an improved quality and about half due to a yield increase). Costs involved in producing such an increase are as follows:

	Amount per acre
1. Irrigation System	
a. Initial cost ($120 per acre amortized over 15 year period at 6% interest)	$ 11.60
b. Cost of operation (including labor for handling) $1.50 per acre-inch of water applied	6.90
c. Repairs and replacement (3% of initial cost)	3.48
2. Cost of handling increased yield (barning, grading, marketing)*	16.10
Total	$ 38.08

Net increase associated with such a cost is:

Gross increase resulting from irrigation	$337.50
Cost of irrigation (amortized schedule)	38.08
Net increase	$299.42

There was no increased cost due to cultivation and fertilization. Increased fertilizer rates were studied but no great differences were found. During such a season (drought expectancy of at least one out of every four

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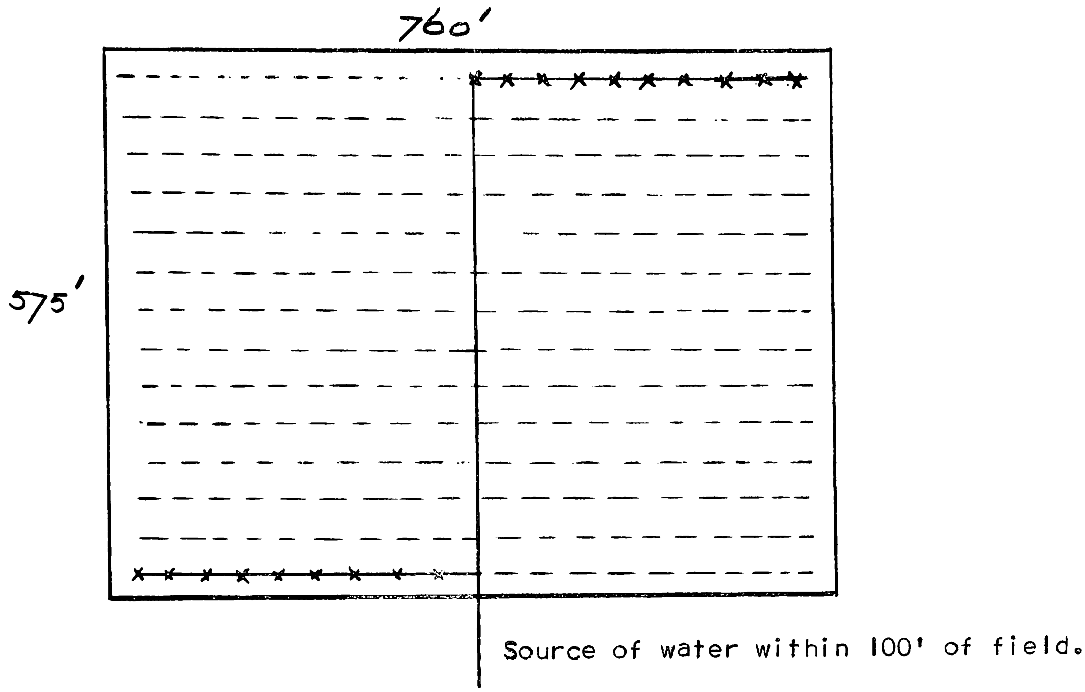
* Estimated - based on labor distribution for growing tobacco as found in "Cost of Producing Farm Products in North Carolina", Pierce and Williams, A.E. Info. Series No. 29 N. C. State College.



10 Acres - Dimensions as shown.

Irrigate 3 set-ups per day - laterals as shown.

Schedule:

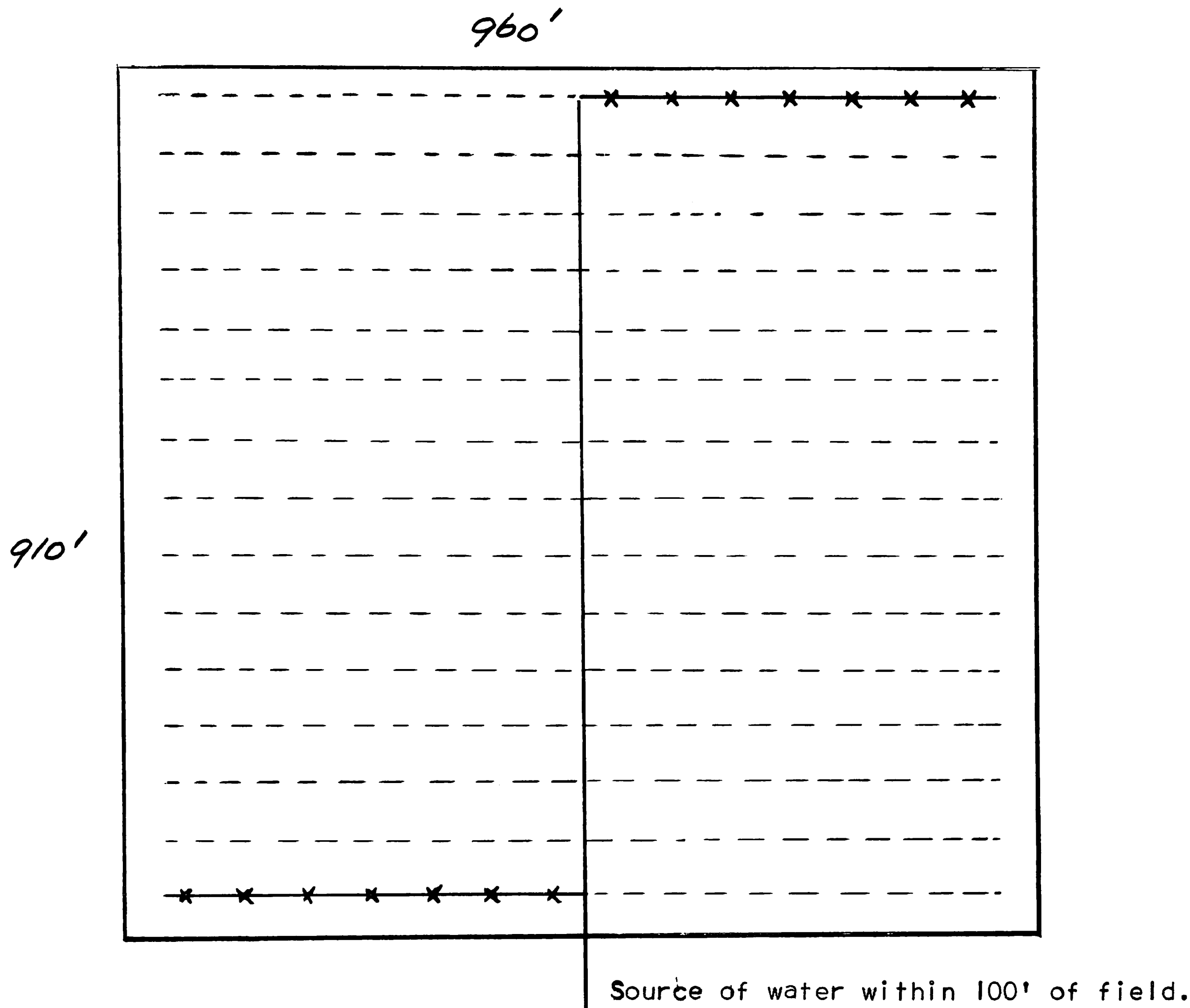
1. Irrigate 5 hrs. in morning, change at noon.
2. Irrigate 5 hrs. in afternoon, change in late afternoon.
3. Irrigate 5 hrs. at night, putting enough gasoline in engine to run 5 hrs. and stop automatically.

Capacity of system: 70 gallons per minute

Bill of materials:

400'	3" al. pipe	$ 260.00
1000'	2" al. pipe	500.00
19	sprinklers at 3.8 gpm ea.	114.00
19	risers w/bushings	11.40
1	3" x 3" x 2" tee w/valve	20.00
1	3" x 2" red. coup.	6.00
1	2" x 2" 90° elbow w/valve	20.00
1	pump to al. adapter	10.00
1	pump, centrifugal, 70 gpm at 60 psi, trailer mtd.	350.00
1	3" x 15' suction hose	60.00
	Total	$1,351.40

Figure 4. Irrigation system layout for 10 acres.



20 Acres - Dimensions as shown.

Irrigate 3 set-ups per day - laterals as shown.

Schedule:

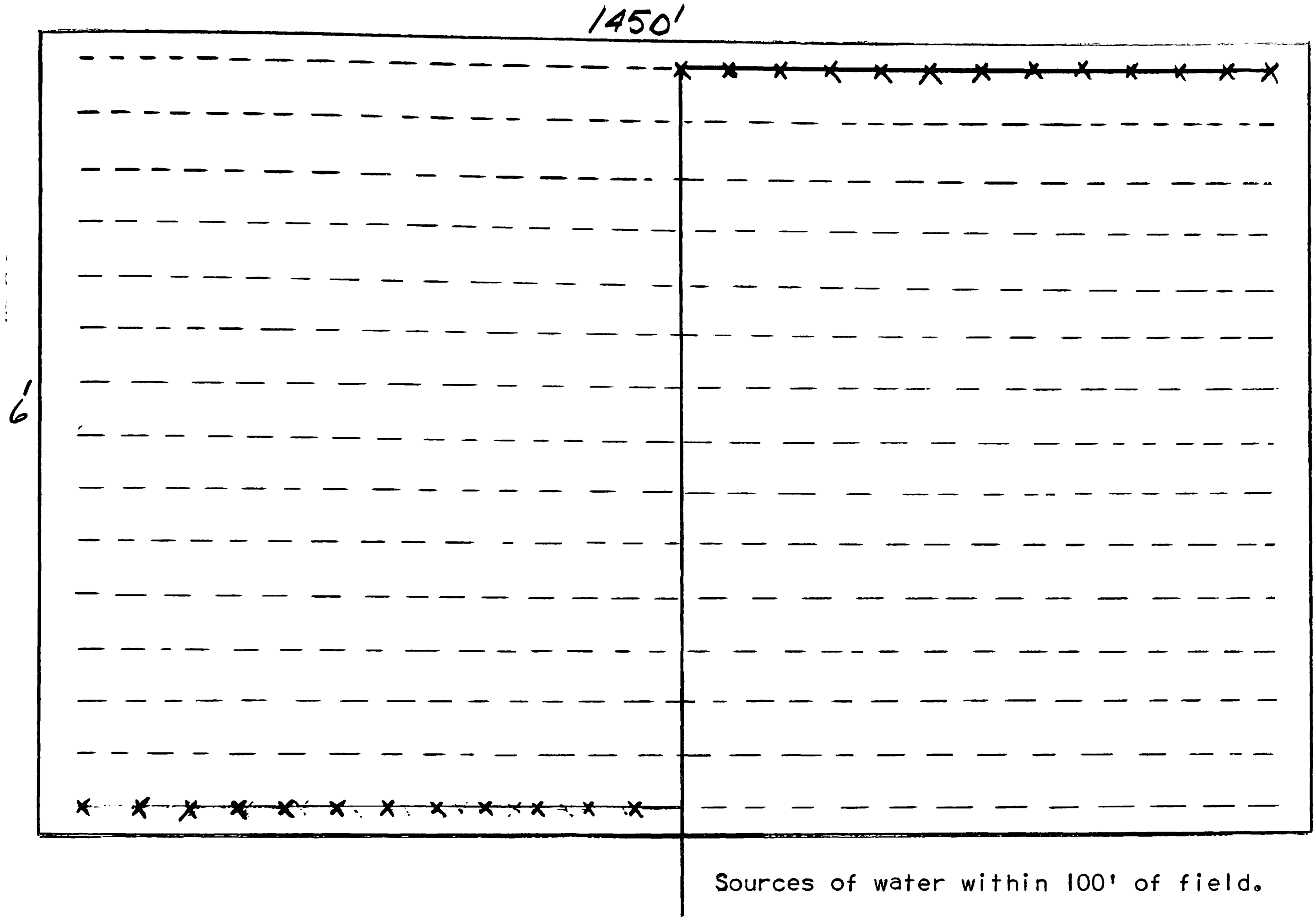
1. Irrigate 5 hrs. in morning, change at noon.
2. Irrigate 5 hrs. in afternoon, change in late afternoon.
3. Irrigate 5 hrs. at night, putting enough gasoline in engine to run 5 hrs. and stop automatically.

Capacity of system: 133 gallons per minute.

Bill of materials:

520'	4" al. pipe	$ 468.00
600'	2" al. pipe	300.00
700'	3" al. pipe	455.00
16	Revolving sprinklers	96.00
16	Risers w/bushings	9.60
1	4" x 4" x 3" tee w/valve	25.00
1	4" x 3" red. coup.	6.00
1	3" x 3" elbow w/valve	20.00
2	3" x 2" red. coup.	12.00
2	2" end caps	3.00
1	pump to al. adapter	10.00
1	pump, centrifugal with gasoline engine 135 gpm at 70 psi, trailer mtd.	600.00
1	4" x 15' suction hose	97.50
	Total	$2,102.10

Figure 5. Irrigation system layout for 20 acres.



30 Acres - Dimensions as shown.

Irrigate 3 set-ups per day - laterals as shown

Schedule:

1. Irrigate 5 hrs. in morning - change at noon.
2. Irrigate 5 hrs. in afternoon - change in late afternoon.
3. Irrigate 5 hrs. at night, putting enough fuel in engine to run 5 hrs. and automatically stop.

Capacity of System: 200 gallons per minute.

Bill of Materials:

540'	5" al. pipe	594.00
420'	4" al. pipe	378.00
960'	3" al. pipe	724.00
480'	2" al. pipe	240.00
25	sprinklers 6-7 gpm	150.00
25	risers w/bushings	15.00
1	5" x 5" x 3" tee w/valve	25.00
1	5" x 4" red. coupling	6.00
1	4" x 3" red. 90° elbow w/valve	14.00
2	3" x 2" red couplings	12.00
1	pump to al. pipe adapter	14.00
1	pump. centrifugal, 200 gpm at 70 psi, trailer mounted with power unit	650.00
		2,822.00

Figure 6. Irrigation system layout for 30 acres.

years) the total cost of the irrigation system could be liquidated and still a greater net profit would result when compared with unirrigated tobacco as follows:

	Amount per acre
Gross increase resulting from irrigation	$337.50
Total cost of system plus operation costs and increased labor costs	143.00
Net increase	$194.50

In 1952 the tobacco growing season was not as droughty as in 1951 at Oxford, although it was considerably more droughty in many areas within the tobacco region of the Southeast. The gross increase resulting from five irrigations (6.4 inches) was $83 per acre for normal plant population (6800 plants per acre). In this case the increase was again about equally divided between quality improvement and yield increase.

		Amount per acre
Gross increase		$ 83.00
Cost of irrigation and handling		
Initial cost of system	$ 11.60	
Operation (6.4" of water)	9.60	
Repair, replacement, etc.	3.48	
Increased cost of handling	3.25	
Total cost		$ 27.93
Net increase		$ 55.07

An equally droughty season can be expected at least one out of every two years according to past weather records. At such a rate, even assuming such seasons as 1951 did not occur, the system could be paid for in six years.

Increasing stand to 10,500 plants per acre resulted in a $175 per acre increase in value when compared with normal stand irrigated, and $258 per acre increase when compared with normal stand unirrigated. The cost of producing tobacco with the increased heavy population was somewhat higher, as follows:

	Increased cost of 10,500 over 6800 plants, $ per acre
Plant bed	$ 1.50
Preplanting (ridging and distributing fertilizer)	.70
Transplanting	9.50
Cultural practices (topping, suckering, etc.)	6.50
Harvesting	60.70
Grading, marketing etc.	14.00
Increase in fertilizer	$ 9.60
Total	$102.50

A comparison of irrigated normal population with irrigated increased population shows:

	Amount per acre
Gross increase	$175.00
Increased cost of producing	$102.50
Net increase	$ 72.50

A comparison of 6800 plants per acre unirrigated with 10,500 irrigated shows:

		Amount per acre
Gross increase		$258.00
Increased cost of production	$102.50	
Cost of irrigating	27.93	
Total cost		$130.43
Net increase		$127.57

As mentioned earlier in this report, work will be continued on heavy plant populations, both irrigated and unirrigated, so that better comparisons can be made.

As indicated by two years of study the economic feasibility of irrigating tobacco looks good. However, recommendations cannot be made on the basis of information available at this time.

Many farmers have purchased irrigation systems at lower costs than indicated in this report, many of which give satisfactory service. Some, however, do not give satisfactory service. Such reductions in cost can be made by purchasing war surplus pumps and power units, by using a farm tractor or other available engine to pull the irrigation pump, etc.

In addition to the encouraging economic aspects, an irrigation system on hand at transplanting time can help considerably in establishing a uniform, almost perfect stand which should also show up in the crop value. A preliminary experiment conducted at the McCullers Station in 1951 showed a 99 per cent survival of plants which were set into dry ground without water and irrigated in late afternoon. Other plants transplanted by the conventional method (plant and a small quantity of water put in ground together) the same day showed only 82 per cent survival. This resulted in a more even stand and cut down on labor costs to some extent.

A summary of the economic analysis of irrigation experiments is given in the following table.

Table 14. Summary of production cost analysis of irrigation experiments with tobacco.

SUMMARY OF 1951 RESULTS		
Item	Irrigated	Unirrigated
Value per acre	$ 925.00	$ 587.50
Cost of irrigation	21.98	
Net increase from irrigation	315.52	
Increased cost of production	16.10	
Net Gain	299.42	
SUMMARY OF 1952 RESULTS		
Irrigated vs. Unirrigated - 6800 Plants Per Acre		
Item	Irrigated	Unirrigated
Value per acre	$ 826.00	$ 743.00
Cost of irrigation	24.68	
Net increase from irrigation	58.32	
Increased cost of production	3.25	
Net Gain	55.07	
Irrigated - 10,560 Plants vs. 6800 Plants Per Acre		
Item	10,560 Plants/Acre	6800 Plants/Acre
Value per acre	$1001.00	$ 826.00
Cost of irrigation	24.68	24.68
Net increase from increased population	175.00	
Increased cost of production	102.50	
Net Gain	72.50	