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DEEP DITCH OVERDRAINAGE AFFECTS WATER TABLE DEPTH AND CROP YIELD

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ABSTRACT

Water table levels and corn yields were measured along a 2-mile section of Mitchell Creek to study the effects of deep ditch overdrainage. The 3-m deep channel affected the water table 834 m from the Creek. Overdrainage affected corn yields under irrigated and nonirrigated conditions.

INTRODUCTION

There are about 40 million hectares of drained farm land in the humid region of the U.S. The Soil Conservation Service estimates that 3.4 million hectares of this farmland in N.C., S.C., Ga., Fla., and Ala. are sandy, sandy loam, and organic soils where the water table should remain within 1 m of the surface to protect the soil from over oxidizing or to provide adequate moisture to sustain crop productivity.

Drainage has been practiced in these soils for many years because excess rainfall may cause the water table to rise to or near the surface occasionally, impeding or completely eliminating crop growth. However, excessively wet soil during one period may be excessively dry soil during another as a result of erratic rainfall distribution and soil conditions in the Southeast. The water-holding capacity of the sandy soil is only about 3 cm/30 cm of soil; enough to supply crop water needs for 5 to 7 days. Consequently, when the soil is drained too deeply by a drainage system, it must rain again within 5 to 7 days to prevent drought stress in the crops. An example of this condition is the Conetoe Drainage District in North Carolina where 26,000 hectares of land are drained by a drainage system constructed in 1967. Several thousand hectares of cropland that once were flooded several times a year are now protected. However, to drain parts of the District, large channels over 2 m deep were necessary. These deep channels draw the water table down too far near the channels and affect the water table more than 800 m away. Although

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flooding is no longer a problem drought and low water table levels are problems, and more farmers are investing in irrigation systems each year. Domestic use well points are being lowered to compensate for a lower water table.

This study will evaluate the effect of deep ditch overdrainage on water table levels and crop yields in the sandy soils of the Conetoe Drainage District.

PROJECT DESCRIPTION AND PROCEDURES

This project is the composite cooperative effort of agencies from the U.S. Department of Agriculture, Agricultural Research Service and the Soil Conservation Service; departments from the North Carolina Agricultural Research Service, Biological and Agricultural Engineering, and Soil Science Departments; the Edgecombe County Drainage District #2; and local farmers and landowners.

The water management study is located on a 2-mile section of Mitchell Creek in Edgecombe and Pitt Counties, North Carolina. The area, about 800 hectares, is flat to gently rolling with no more than a 1.5-m difference in elevation. The soil series Altavista, Augusta, Cape Fear, Conetoe, Portsmouth, Roanoke, State, Tarboro, and Wahee were mapped for each yield sample site by the Soil Conservation Service. The soils are poorly to somewhat excessively drained, formed in sandy fluvial and marine sediments. They are underlain by a coarse sand aquifer at about 1.5-m depth. A layer of blue, impermeable clay is below the coarse sand ranging in depth from 4 to 8 m below the surface.

Six lines of water table observation wells were installed to transect the area on each side of the creek. Well locations ranged from 10 to 860 m from the channel in lines perpendicular to the creek. Forty wells were equipped with stage recorders and 22 were read manually each week. There were 12 stream gaging sites equipped with stage recorders. Manual flow measurements were made at 5 of these sites about twice weekly. Other sites were measured about once a month.

Water table depth-days (WTDD) were determined from the recorder charts. The WTDD is a measurement of the water table depth for the growing season, with the highest WTDD showing the deepest water table depth from the surface. For example, a WTDD is 0.5 if the water table is 0.5 m, 1.0 if the water table depth is 1.0 m, or 2.0 if the water table depth is 2.0 m from the surface for any individual day. The WTDD were then summed for the growing season and plotted against distance from the channel. For this report, the distance from the channel was divided into four sections 0-200 m, 201-400 m, 401-600 m, and greater than 600 m. These sections were considered as treatments and the significance of treatment differences were determined by analysis of variance. The average distance and average WTDD were then used to determine the regression. Corn yields were also compared with the WTDD.

Corn yields were sampled by hand from 2 replications near each analyzed in the same manner as WTDD and distance.

A fabridam-type structure (2.7 m high) is being constructed across Mitchell Creek about midway in the 2-mile study area. The water inflatable fabric dam is about 6 m wide at the bottom of the creek bed and 13 m wide at bank height. The structure will be used to automatically control the water level in the creek upstream.

RESULTS AND DISCUSSION

Drainage research (Wesseling 1974) has shown that if the water table is too close to the surface, yields will be reduced due to O_2 stress (Fig. 1).

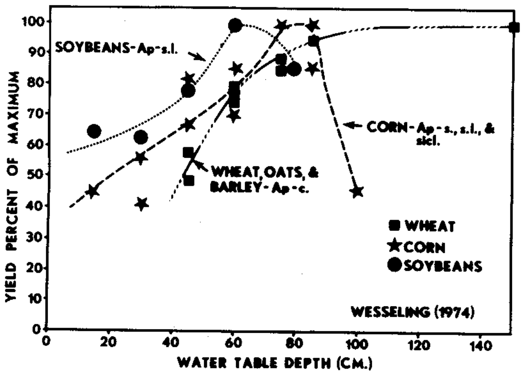

Fig. 1. Water table depth vs. percent of maximum yield for major field crops (after Wesseling 1974).

When the water table in sands, sandy loams, and silty clay loam soils rose from 80 to 15 cm below the surface, corn yields decreased from 100 to 45% of maximum yield, respectively. Likewise, when the water table fell from 80 to 100 cm below the surface, corn yields decreased from 100 to only 45% of maximum, respectively. Soybeans growing on sandy loam soils were similarly affected. Yields for wheat, oats, and barley growing on clay soil were somewhat similar for a rise in water table, but 100% of maximum yield was reached at a water table depth of 150 cm. Vegetable crop yields followed about the same trends (Wesseling 1974). The fact that there were no yield decreases as the water table receded in clay soils indicated the water-holding capacities of the clay soils (6.4 cm/30 cm of soil) to be higher than sandy soils (1.5 to 5 cm/30cm of soil) (Turner et al., 1971).

Drainage by a Deep Ditch

For the sandy soils, the 2 to 4-m deep Mitchell Creek is an excellent stream for drainage and flood control. However, overdrainage occurs after the flooding has passed. Figure 2A shows the water table elevations on each side of Mitchell Creek for well line No. 5. The water table slopes towards the channel to the measured distance of 834 m on the right side and to 696 m on the left side. The water table slope is greater for the first 400 m. Similar slopes of the water table occur about 1200 m upstream at well line No. 3 (Fig. 2B) where the soil surface is relatively flat. This indicates that water is being drained by Mitchell Creek from a distance of at least 834 m. If the highest water table level is assumed to be the point where crops can be grown without aeration problems in these fields, the difference in the highest and lowest levels of the water table is the amount of overdrainage that occurred in 1980 (Fig. 2A, 2B).

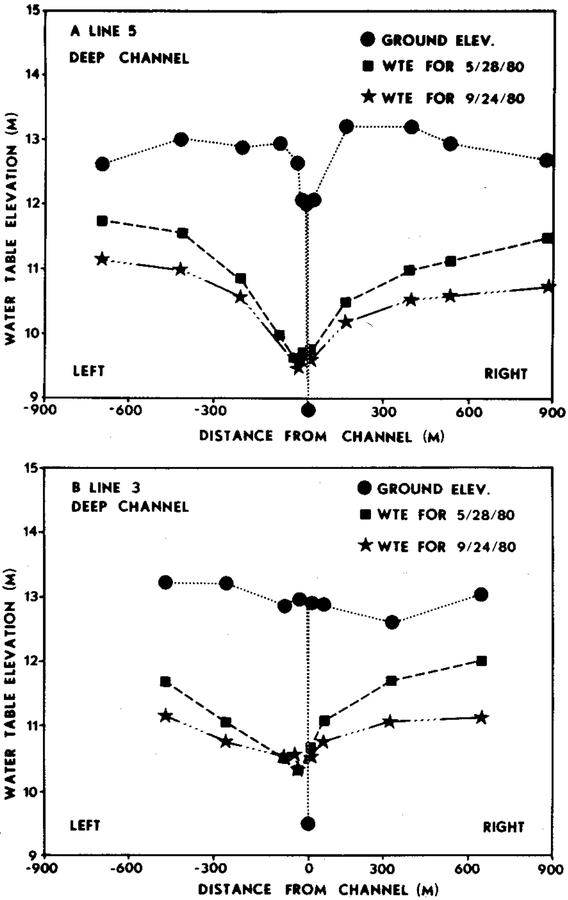

Fig. 2A & 2B. Water table in relation to distance from Mitchell Creek, Well Line #5 (A) and Well Line #3, (B).

The amount of overdrainage is shown with time in Fig. 3A for well line No. 5. At the beginning of data collection in 1980, a well located 594 m away from Mitchell Creek indicated the water table to be at an elevation of about 11.5 m, the lowest elevation at which the water table should be maintained at that point. But the water table elevation continued to drop to an elevation of 10.8 m throughout the remainder of 1980 and on through 1981. A well 18 m from Mitchell Creek was at an elevation of 9.5 to 10.0 m which is at least 1.5 m below the desired water level of about 1 m below the soil surface for the same period of time (Fig. 3A). The elevation of the water table level in the creek was less than 9.6 m throughout 1980 and 1981. The water level in the creek should remain between 10.6 and 11.5 m to prevent overdrainage of soils. Similar results are shown for well line No. 3 about 1200 m upstream (Fig. 3B).

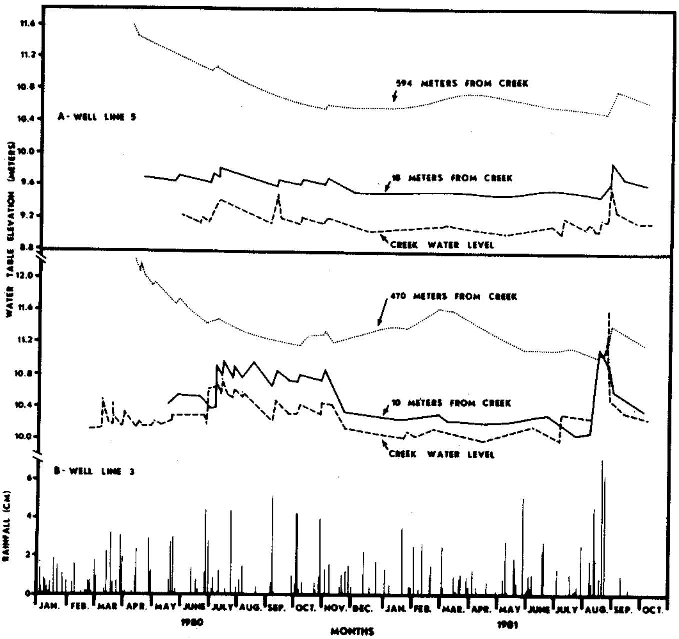

Fig. 3A & 3B. Relation of stream water elevation fluctuation to water table fluctuation near Mitchell Creek and at a distance away from Mitchell Creek at Well Line #5(A), and Well Line #3(B).

An indication of success in controlling the water levels was apparent when a landowner built an earthern dam across Mitchell Creek about 100 m downstream from well line No. 3 on August 5, 1981 to control the water level in the creek for irrigation pumping (Fig. 3B). The water level in the stream reached an elevation of 11.0 m, which is less than 1 m below the planned control level using the fabridam structure. Within 13 days after the structure was installed, the water table level at 15 m and 470 m away from Mitchell Creek rose about 0.8 m and 0.02 m, respectively, after a 5.8 cm rain. This shows that drainage can be decreased by controlling the water level in the creek. On August 23, 1981, a heavy rain washed out the earthern dam, and the water levels in the creek and 15 m from the creek dropped rapidly. At 470 m from the creek the drainage was slower, but decreased steadily at about 0.01 m/day for the next 35 days. This 0.4-m drop was overdrainage of the area.

Winner and Simmons (1977) predicted similar results on the creeping swamp watershed in North Carolina. If the channels in creeping swamp were deepened, a greater drop in the groundwater level would occur, with the greatest change near the stream and relative little change at the divide. Our data indicate more fluctuation at 800 m from Mitchell Creek, but this might not be the case, if the soil profile was full nearer the creek before drainage started. Simmons and Aldridge (1980) reported that during dry periods, a direct relationship between stream stage and discharge and the water levels in nearby shallow wells. Therefore, by controlling the stream flow with the fabridam, the drainage of the stored water under the fields should be slowed and much of the water retained in the water table would not flow down Mitchell Creek to the Tar River and on to the Atlantic Ocean. The retained water may then be utilized by the crops or stored underground to be pumped from the stream for irrigation as needed. The 2- to 6-m thick coarse sand aquifer is ideal for storing water for use during dry periods.

Water Table Depth-Days and Crop Yields

The sum of the average growing season water table depth-days (WTDD) for each well where corn samples were taken was plotted against the average distance from Mitchell Creek (Fig. 4A). Water table depth is related to the distance from Mitchell Creek, as shown by the decrease in WTDD at wells farther from the creek. The analysis of variance showed significant difference between the WTDD at less than

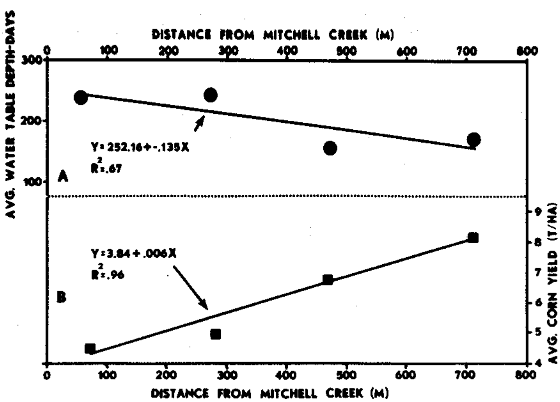

Fig. 4A & 4B. Relation between the average water table depth-days (A) (WTDD) and yield average (B) of 0-200, 201-400, 401-600, and greater than 601 m from Mitchell Creek.

300 m from Mitchell Creek and at distances greater than 400 m from the creek.

The variation (r^2=.96) in the average nonirrigated corn yield and average distance data for 1980 and 1981 was small. The regression (Fig. 4B) shows corn yields of about 4.5 t/ha at 70 m from the creek and about 8 t/ha at 710 m from the creek. The analysis of variance showed significant differences between the average yield at less than 300 m from Mitchell Creek and the average yield at greater than 400 m from the creek. The increase in yield corresponding to the increased distances from the creek shows that deep ditch overdrainage in the sandy soils is a real factor influencing crop yields. Yield increases as the number of WTDD decreased (Fig. 4A & 4B) show that the soils were overdrained near Mitchell Creek.

Figure 5 shows the relationship of corn yield grown in a Portsmouth soil to WTDD. For example, from 91 to 130 m-days (or total of depth-days about 700 m from the creek) corn yield ranged from 7.2 to 10.0 t/ha, but at about 225 m-days (less than 50 m from the creek), the yield ranged from 1.8 to 5.6 t/ha. The deep water table near the creek was affecting crop yields.

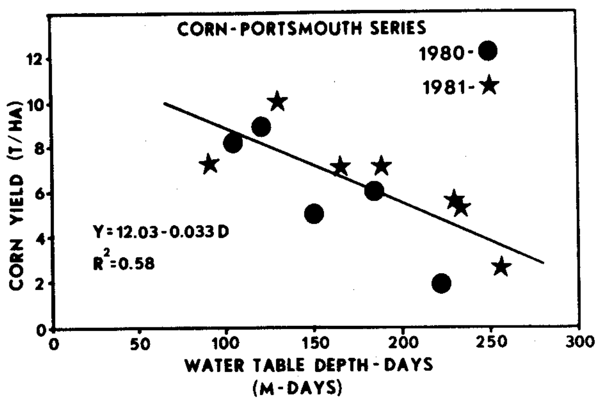

Fig. 5. Relation of corn yield to water table depth-days (WTDD) in a Portsmouth soil.

In 1981 corn yield were 7.2 and 10.0 t/ha for 91 and 128 WTDD at 727 and 696 m from Mitchell Creek, respectively. At distances of 12 and 186 m from Mitchell Creek, the yields were 1.8 and 2.8 t/ha for 222 and 256 WTDD, respectively (Fig. 5).

These results concur with those reported by Wesseling (1974) (Fig. 1). Even though the average water table was deeper in 1981 than in 1980 (Fig. 3), our results indicate that the overdrained areas near Mitchell Creek, where the water table was the deepest, produced lower yields than the areas 700 to 800 m from the creek where the water table was shallower (Fig. 5).

Irrigated corn in 1980 (Fig. 6) also shows the effects of overdrainage on crop water need and crop yield. Irrigation was applied one time to one field by a volume gun system. In another field, full season irrigation was applied by a center pivot system. Corn grown 300 m from Mitchell Creek produced about the same yields whether it had only one irrigation or full season irrigation. However, at 25 to 50 m from Mitchell Creek, the corn with full season irrigation produced 6 to 7.5 t/ha more than the corn receiving only one irrigation (Fig. 6). More irrigation water was required to produce greater yields near the creek, and more water was removed by overdrainage near the creek than at 300 m from the creek as shown in Fig. 2 and 3.

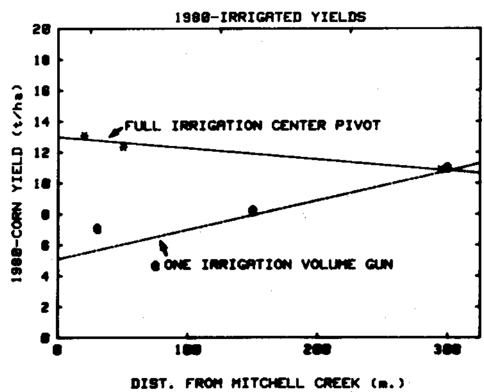

Fig. 6. Irrigated corn yield vs. distance from Mitchell Creek in 1980.

SUMMARY AND CONCLUSIONS

The data collected in this and other studies have shown that when the water table rises too close to the soil surface, or falls too far below the soil surface, yields are reduced below the maximum. Therefore, there is a water table depth at which maximum yield occurs, and the water table should be controlled at that level assumming erratic rainfall distributions.

In the Mitchell Creek Project in Edgecombe and Pitt Counties, North Carolina, the effects of deep ditch overdrainage were evaluated. The 3-m deep channels in Mitchell Creek affected the water table 834 m from the creek. Overdrainage was also shown by the average water table depth-days which were about 250 m-days near the creek and 150 m-days at 800 m from the creek.

Overdrainage affected corn yields under irrigated and nonirrigated conditions. Yields at 800 m from the main channel were greatest with reduced yields at distances closer to the main channel. These effects were studied on all soil series where corn yields were measured.

Overdrainage is occurring in the low water-holding capacity sandy soils with deep channelization throughtout the Southeast. Shallow channels would probably decrease overdrainage, but maintenance, flood control, and proper drainage during wet periods are problems that would still exist. Engineering design criteria must be established for future planning of water resource projects that will provide proper drainage and flood control during wet periods and still provide soil water storage in the soil profile and in the stream channels for supplying water for crop needs either by capillary rise in the soil or by being available for irrigation pumping.

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