# RESPONSE OF WHEAT TO FERTILIZERS ON TOPSOIL AND SUBSOIL

by

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# INTRODUCTION

The purpose of this study was to determine the productivity of soil exposed by removing the top 20 cm from Smolan silty clay loam. An effort was made to determine the best method or combination of methods for improving the productivity of the exposed subsoil.

With a steady increase in world population and a lack of new land to farm, man has found it necessary to reclaim much of the less productive land which was abandoned because its unproductive subsoil has been exposed.

The infertility of subsoil has long been recognized. If surface soil or exposed subsoil has poor structure and low water intake rate, it is likely that there will be greater loss of runoff water and also greater erosion than on topsoil. As a consequence, there may be less water for plant growth. The structure of subsoil is likely to break down upon exposure because of a lack of organic matter.

Land leveling operations for irrigation leave many acres of exposed subsoil. The productivity of these leveled lands depends on the general fertility of the exposed soil, the degree of mixing of soil horizons, and the physical characteristics of these soils.

On subsoil with hard and firm consistency considerable difficulty usually is experienced in getting crop stands. This difficulty is usually caused by cloddiness and other factors related to the soil's structural characteristics.

The usual recommendations for bringing such problem subsoils back to full productive capacity have been to seed the area to legumes in initial years. In later years these exposed soils are seeded to non-leguminous crops with frequent rotations with legume crops. Because of the loss of time, loss of production and expenses involved, a simpler and faster method of reclaiming these soils is needed.

When subsoils have good physical characteristics and a sufficient moisture supply, the response of crops grown on them to chemical fertilizers may be satisfactory. The amount of fertilizer required may be greater for subsoil than for topsoil, since subsoil usually is not as fertile as topsoil. Low organic matter content, low nitrogen content and low phosphorus content are the main causes of a lack of fertility in exposed subsoils. Low Zn is usually an important factor in low yields on subsoil in Kansas.

The term topsoil refers to the surface layer with maximum organic matter accumulation or the Ap horizon. The term subsoil refers to all other horizons underlying the surface layer or topsoil including the B, C, and D horizons (32). In this study subsoil refers to the upper portion of the B horizon.

## REVIEW OF LITERATURE

Much work has been done to determine the causes of unproductiveness of subsoils and to find satisfactory methods of reclaiming them; however, a wide variety of results have been obtained.

Alway, McDole and Rost (1), using Nebraskan loess topsoils and subsoils in a greenhouse experiment, showed that the subsoils were less productive than topsoils when corn was grown. The soils they used showed no rawness[1/] toward inoculated legumes but were unproductive with non-legume crops. Harmer (18) found some Minnesota glacial subsoils to be as productive as surface soils for growing alfalfa if inoculation was practiced. Other soils were quite unproductive and the lack of weathering was not associated with an especially low nitrogen content nor with soil acidity. The same subsoils were found to be as productive as topsoils by McMiller (23) when applications of potash and phosphate fertilizers were made.

Working with Cecil sandy loam, Latham (20) found the A horizon to be three times more productive than the B horizon and 11 times more productive than the C horizon. Organic matter additions in the form of stable manure resulted in increased yields from all horizons, with the greatest effect occurring on the C horizon.

Gardner (13) found that decreased crop yields following loss of surface soil was caused by a deficiency of available phosphorus and nitrogen. In a field experiment, Robertson and Gardner (25) observed a 107% increase in barley yields with the addition of superphosphate to subsoil plots. They concluded that phosphorus was a major cause of low yields on the subsoil.

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[1/] Rawness was used in this article to describe subsoils which had not undergone sufficient weathering to produce natural fertility.

Smith and Pohlman (26) compared yields from fine textured subsoils and three surface soils in a greenhouse study using barley, Korean lespedeza, sudan grass and red clover grown in succession. In most cases yields from the surface soils were greater than those from subsoils even after lime, phosphorus, and potassium were added to the subsoils. Yields from manure treatments generally were not superior to those from soils receiving fertilizer treatments.

Bachtell, Willard and Taylor (2), in Ohio, found that yields were increased on subsoil by fertilizer applications after the first year of study. After 20 years of cropping with rotations, yields from subsoils were not equal to those grown on topsoils. Manure treatments were as effective or even more effective in increasing yields on subsoil as compared to topsoil.

Greenhouse and field experiments were conducted on Pullman silty clay loam by Eck, Hauser and Ford (8). Nitrogen fertilizers were required to obtain maximum yields of grain sorghum on undisturbed soil and also on soils with various depths of cut. Nitrogen and phosphorus fertilizers restored yields when applied to areas from which up to 30 cm of topsoil was removed.

Carlson, Grunes and Alessi (5) at Upham, North Dakota, found that when adequate amounts of nitrogen and phosphorus fertilizers and manure were applied to subsoil, corn forage yields were equal to those on topsoil. In 1954 yields from topsoil and subsoil under similar high treatments were similar; however, in 1956 yields on the topsoil plots were twice those on subsoil under similar treatments. Alfalfa increased the nitrogen content of subsoils and thus reduced the amount of nitrogen fertilizer needed on the exposed subsoil areas. Mixing some surface soil with subsoil during the land leveling operation markedly reduced the need for phosphorus fertilizer.

Applications of nitrogen, phosphorus, zinc, and manure were found by Carlson et al. (6) to increase yields from subsoil to equal those from topsoil. Engelstad and Shrader (10) compared corn yields on cuts of various depths and found that without nitrogen fertilizer yields were strongly dependent upon surface soil thickness. It was found by Engelstad, Shrader, and Dumenil (11) that the ability of nitrogen fertilizer to substitute for surface soil thickness was dependent upon climatic factors.

Reuss and Campbell (24) showed in greenhouse and field studies that subsoils were highly deficient in both nitrogen and phosphorus. They found no evidence that physical properties or trace element deficiencies limited plant growth.

Eck and Ford (9) used Amarillo, Dalhart, and Miles soils in a greenhouse study with German millet. They found that nitrogen was more limiting than phosphorus on the topsoil, but phosphorus was more limiting than nitrogen on all subsurface horizons. They concluded that the subsurface of some soils was more productive than the topsoil. This could be understood if a soil had a buried horizon near the surface but otherwise would be rare. In some instances they found that fertilizer can cause yields on subsoils to equal yields on topsoils. Mixing of fertile topsoil with less fertile subsoil was found to improve yields on exposed subsoil.

Using orthic brown chernozemic soils in a plot experiment, Lutwick and Hobbs (21) found that highest yields and phosphorus uptake were obtained when alfalfa was grown on soil having an A horizon. Yield response to manure and phosphate was greatest on soils containing no A horizon materials. The yields on fertilized subsoil were about the same as those on unfertilized topsoil.

After studying the phosphorus status of various horizons of four benchmark loessial soils of the central Great Plains Region, Black and Whitney (3) concluded that when adequate nitrogen and phosphorus fertilizers were used, yields from the subsoils were only slightly less than yields obtained from the surface soils.

Smith, Henderson, and Cook (27), using Austin clay, reported quick partial recovery from extremely low productivity on desurfaced plots. Fertility was slow to improve with no fertilizer applications or with additions of phosphorus only. They found erosion was greater on desurfaced plots than on normal soils.

Using four Kansas soils -- Marshall, Richfield, Geary[2/], and Ladysmith -- d'Hiriart (7) showed that in greenhouse studies lower fertility status of the subsoil, determined by general fertility tests, was an important cause of reduced crop growth on these subsoils. In the case of Marshall and Ladysmith soils, low fertility was apparently the major cause of reduced productivity. With the Richfield and Geary soils he found that the fertility treatments employed did not overcome the detrimental effect of topsoil removal.

Most researchers have found deficiencies of nitrogen and phosphorus to most frequently limit yields on subsoils; however, the reaction of subsoils to chemical fertilizers and manure vary widely. Physical properties of the subsoil and depth of soil removed all determine the relative productivity of subsoil to topsoil.

## MATERIALS AND METHODS

In field studies the productivity of Smolan silty clay loam topsoil was compared to the productivity of its subsoil in successive field experiments.

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[2/] The sample site of this soil has been reclassified as Smolan.

Land on which this study, called the Decapitation Study, was located had been under cultivation since 1864. It was planted to corn, wheat and occasionally oats until 1909, when a soil fertility project was started by L.E. Call (12). This site is located on the Agronomy Research Farm, Kansas State University, Manhattan, Kansas.

The soil was tentatively classified for many years as Geary silty clay loam. The Geary series is classified Udic Argiustoll. In recent years the soil has been classified Smolan silty clay loam (see Appendix Table 30), a member of the fine, montmorillonitic mesic family of the Pachic Argiustolls. Geary has less than 35% clay in the composite control section; whereas, Smolan has more than 35% clay in the composite section.

The study consisted of three replications of eight plots each with dimensions of 6.7 m by 17.7 m. East-west alleyways between plots were 5.2 m wide. North-south roadways and turnrow areas were 6.4 m wide or wider. Each plot was laid out across the general slope in such a way that runoff water drained to the down-slope side of the excavated plots where it was channeled to a waterway. Small ridges were formed at the lower edge of each alleyway to intercept runoff water at the uphill side of the plots. This was done to prevent excavated plots from receiving excess water from surrounding areas. Crops were planted lengthwise of the plots so that the rows were across the general slope of the field.

There was a 1 to 4% slope on the experimental site. Because of soil variability and erosion resulting from past use, topsoil depth varied widely. On part of the site subsoil had been mixed with what topsoil remained. On the south end of the site the thickness of the A horizon was equal to or greater than 20 cm. On the north end of the site the A horizon was less than 20 cm thick.

Half of the plots in the study had 20 cm of soil removed with a bulldozer in the summer of 1968. The excavation process removed only part of the A horizon on plots at the top of the slope; whereas, all or nearly all of the A horizon was removed by excavation on the low side of the field.

The fertilizer treatments applied to the plots are given in Tables 1 and 2. The treatments were based on experiences from a previous soil fertility study on the site and common knowledge of soils in the area where the study was located. The lowest rate used was the rate commonly recommended for average soil conditions in eastern Kansas.

After tilling and proper fertilization, plots were seeded to wheat on October 29, 1968, at a rate of 84 kg/ha. Additional ammonium nitrate was used to topdress the wheat in mid-March 1969. Harvest was done by a small combine.

During the summer of 1969, manure was added to the appropriate plots but weather prevented the fall planting of wheat. Pioneer 845 grain sorghum was planted June 23, 1970, on the field using a two row planter. Appropriate fertilizer rates for grain sorghum (Table 2) were applied to each plot at seeding. Due to a lack of moisture, a poor stand was obtained and the crop was plowed under on July 25, 1970, and tillage was performed to prepare a seedbed for the fall wheat crop.

Plots were seeded to wheat on October 4, 1971. No additional fertilizer was applied because the treatments for the abandoned grain sorghum, applied in June, were considered adequate. Harvest was done by hand on June 23-25.

The following measurements were taken from the 1971 crop.

(a) Emerged plants per 15 dm of row. An average of three hand counts

Table 1. Fertilizer treatments for wheat

| Treatment | Excavation | Fertilizer Application Rates | | |
|---|---|---|---|---|
| | | N | P | Manure |
| | cm | kg/ha | kg/ha | T/ha |
| Low | none | 33.6 | 14.78 | 0 |
| Med. | none | 67.2 | 29.57 | 0 |
| High | none | 100.8 | 59.14 | 0 |
| High Manure | none | 100.8 | 59.14 | 44.8 |
| Low | 20 | 33.6 | 14.78 | 0 |
| Med. | 20 | 67.2 | 29.57 | 0 |
| High | 20 | 100.8 | 59.14 | 0 |
| High Manure | 20 | 100.8 | 59.14 | 44.8 |

Table 2. Fertilizer treatments for grain sorghum

| Treatment | Excavation | Fertilizer Application Rates | | |
|---|---|---|---|---|
| | | N | P | Manure |
| | cm | kg/ha | kg/ha | T/ha |
| Low | none | 56.0 | 14.78 | 0 |
| Med. | none | 112.0 | 29.57 | 0 |
| High | none | 168.0 | 59.14 | 0 |
| High Manure | none | 168.0 | 59.14 | 44.8 |
| Low | 20 | 56.0 | 14.78 | 0 |
| Med. | 20 | 112.0 | 29.57 | 0 |
| High | 20 | 168.0 | 59.14 | 0 |
| High Manure | 20 | 168.0 | 59.14 | 44.8 |

per plot was made on October 16, 1970.

(b) Date heading

(c) Heads per 15 dm of row. An average of three hand counts per plot was made at harvest.

(d) Yields in kg/ha

(e) Test weight in kg/hl

(f) Protein content of grain was determined by the modified Kjeldahl method (16).

Consumptive use of water by wheat on each plot was measured using a Nuclear Chicago Neutron Probe Moisture Meter. Aluminum access tubes, 183 cm long, were placed near the center of plots in replications II and III using a probe truck to bore the holes and install the tubes. Weekly moisture measurements were made at 15 cm intervals to a depth of 183 cm. The readings were taken from the beginning of rapid growth in the spring, April 22, until harvest, June 26, 1971. Some of the wheat was injured while installing access tubes and while taking weekly moisture readings. Areas where the wheat was injured were avoided at harvest.

Two calibration sites with two 183 cm access tubes each were prepared to furnish data for a calibration curve used to interpret probe readings (Table 28). The area around each site was flooded with water until the soil was near saturation to a depth of at least 183 cm. Readings were taken at 15 cm intervals from one of the access tubes at each calibration site. At the same time four soil samples were taken from each site for gravimetric moisture determination. Bulk density samples were taken also at 15 cm intervals near each calibration site. The bulk density was then used to calculate the percent water by volume. These data furnished information for what was called the wet end of the calibration curve.

Sorghum was planted on the calibration sites to extract as much moisture as possible from the soil. In late August gravimetric moisture measurements and probe readings were again taken to determine the dry end of the calibration curve. Data for the wet and dry ends of the calibration curve were used to calculate a regression equation used for converting the probe readings to percent water by volume. Details are given in the Appendix, page 42.

After wheat harvest in early July 1971, infiltration rates were determined by ring infiltrometers (18) on the low topsoil and low subsoil plots and the high manure topsoil and high manure subsoil plots. Cylinders 30 and 46 cm in diameter were used in the study. A hook gauge and engineer's ruler were used to measure the water surface elevation at elapsed times of 5, 10, 15, 30, and 60 minutes. The data were compiled to show accumulative intake and intake rates (Tables 7 and 8).

A general fertility test was made on samples from each plot after harvest.[3/] Soil pH was determined on a 1:1 soil to water ratio. Available phosphorus was determined using a modification of Dickman and Bray's method (4). Exchangeable potassium was determined by extraction with 1N ammonium acetate (4) followed by analysis with a flame photometer. Graham's method of wet digestion (15) was employed to determine the organic matter content. The available nitrogen content of soil samples taken from each plot in September was determined. Available nitrogen was determined by a micro Kjeldahl method (4).

## RESULTS

### Results 1969

In 1969 there was no significant difference in yields of wheat grown on

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[3/] Samples were analyzed by the Kansas State University Soil Testing Laboratory.

topsoil and subsoil. Yields on topsoil averaged 1841 kg/ha compared to 1820 kg/ha on subsoil. The yields ranged from 1411 kg/ha to 2150 kg/ha. The average yield was 1829 kg/ha. There was a significant interaction between topsoil-subsoil and fertility treatments due to a general increase in yield with increased amounts of fertilizer on subsoil and no increase in yields with increased amounts of fertilizer on topsoil (see Tables 3, 9, and 10). All reports of statistical significance are given at the five percent probability level unless otherwise stated.

The test weight of grain from the subsoil plots was significantly greater than the test weight of grain from the topsoil (Tables 11 and 12). Increased amounts of fertilizer caused a slight increase in test weight but this increase was not statistically significant. Average test weight of grain from the topsoil plots was 72.20 kg/hl and 75.37 kg/hl from subsoil plots.

Table 3. Average yields, test weights and percent protein for each fertility treatment.

| Treatments | 1969 Yield | 1969 Test Wt. | 1971 Yield | 1971 Test Wt. | 1971 Protein |
|---|---|---|---|---|---|
| | kg/ha | kg/hl | kg/ha | kg/hl | percent |
| Low Topsoil | 1827.6 | 73.17 | 4213.2 | 82.20 | 14.06 |
| Med. Topsoil | 1926.6 | 72.61 | 3918.0 | 82.07 | 14.23 |
| High Topsoil | 1590.6 | 71.03 | 4686.0 | 81.42 | 14.29 |
| High Manure Topsoil | 2004.0 | 72.01 | 4491.0 | 81.60 | 14.42 |
| Low Subsoil | 1409.4 | 72.01 | 3411.6 | 81.38 | 11.67 |
| Med. Subsoil | 1740.6 | 76.65 | 3516.6 | 81.77 | 12.48 |
| High Subsoil | 1973.4 | 74.55 | 4083.6 | 81.86 | 12.31 |
| High Manure Subsoil | 2158.8 | 74.42 | 4097.4 | 81.86 | 14.46 |

Results 1971

Yields of wheat from the topsoil in 1971 were significantly greater than yields from the subsoil. There was no significant difference due to fertility treatments at the 5% probability level; however, the difference was significant at the 10% probability level (Table 3). Yields ranged from 1989 kg/ha to 4872 kg/ha with an average of 4032 kg/ha. The average yield from topsoil was 4327 kg/ha. The average yield from subsoil was 3777 kg/ha.

Test weights of grain from topsoil and subsoil plots were not statistically different and there was no response to fertility treatments (Table 3). There was an interaction of topsoil-subsoil with fertility treatments due to a slight increase in test weights of grain on subsoil with increased fertility treatments while on topsoil there was a slight decrease in test weights with increased fertility treatments.

Protein content of the grain from the topsoil plots (14.25%) was significantly higher than protein content of grain from the subsoil plots (12.73) (Table 3 and Table 18). There was a significant increase in protein content due to fertility treatments on subsoil plots while there was no increase of protein content due to fertility treatments on topsoil plots. This difference in response to fertility treatments on topsoil and subsoil caused a significant interaction.

The number of plants that emerged, measured soon after planting in 1970, showed the number of plants was greater on the subsoil plots (Table 4). There were no significant differences due to fertility treatments. The average number of plants on the topsoil plots was 82 per 15 dm while the average number of plants on the subsoil plots was 96 per 15 dm. These findings were in contrast to the number of heads counted at harvest (Table 4). In this case

Table 4. Average number of plants per 15 dm, heads per 15 dm, and tillers per plant for each treatment.

| Treatments | Plants | Heads | Tillers |
|---|---|---|---|
| | 1971 | | |
| | Number/15 dm | Number/15 dm | Number/plant |
| Low Topsoil | 84.33 | 247.33 | 2.97 |
| Med. Topsoil | 78.00 | 292.67 | 3.78 |
| High Topsoil | 90.67 | 290.33 | 3.26 |
| High Manure | 76.00 | 318.61 | 4.24 |
| Low Subsoil | 100.33 | 204.00 | 2.05 |
| Med. Subsoil | 96.00 | 224.00 | 2.34 |
| High Subsoil | 95.33 | 294.33 | 3.10 |
| High Manure | 93.33 | 292.00 | 3.14 |

the number of heads per 15 dm were significantly greater on the topsoil plots (287) than on the subsoil plots (254).

Tillering was significantly higher on the topsoil than on the subsoil (Table 24). There was no significant interaction between topsoil-subsoil and fertility treatments. The average number of tillers per plant was 3.56 on topsoil and 2.66 on subsoil.

The average bulk density of the soil at planting in the fall of 1970 (Table 5) was greater for the topsoil (1.26 $g/cm^3$) than for the subsoil (1.16 $g/cm^3$). The lower bulk density of the subsoil at the time of planting was associated with increased plant emergence on the subsoil.

Using the neutron probe to determine the moisture in plots of two replications, no significant difference could be found in the consumptive use of water due to topsoil removal nor due to fertility treatments (Table 6).

Table 5. Average bulk density at planting for each treatment.

| Treatment | Bulk Density |
|---|---|
| | $g/cm^3$ |
| Low Topsoil | 1.23 |
| Med. Topsoil | 1.32 |
| High Topsoil | 1.30 |
| High Manure Topsoil | 1.17 |
| Low Subsoil | 1.09 |
| Med. Subsoil | 1.25 |
| High Subsoil | 1.18 |
| High Manure Subsoil | 1.12 |

Table 6. Average consumptive use of water for treatments from April 22-June 26, 1971.

| Treatments | Consumptive Use |
|---|---|
| | cm |
| Low Topsoil | 28.85 |
| Med. Topsoil | 31.14 |
| High Topsoil | 26.52 |
| High Manure Topsoil | 29.08 |
| Low Subsoil | 27.74 |
| Med. Subsoil | 30.30 |
| High Subsoil | 30.63 |
| High Manure Subsoil | 29.57 |

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Fig. 1. Accumulative water intake in cm for low subsoil (LS), high manure subsoil (HMS), low topsoil (LT), and high manure topsoil (HMT) treatments.

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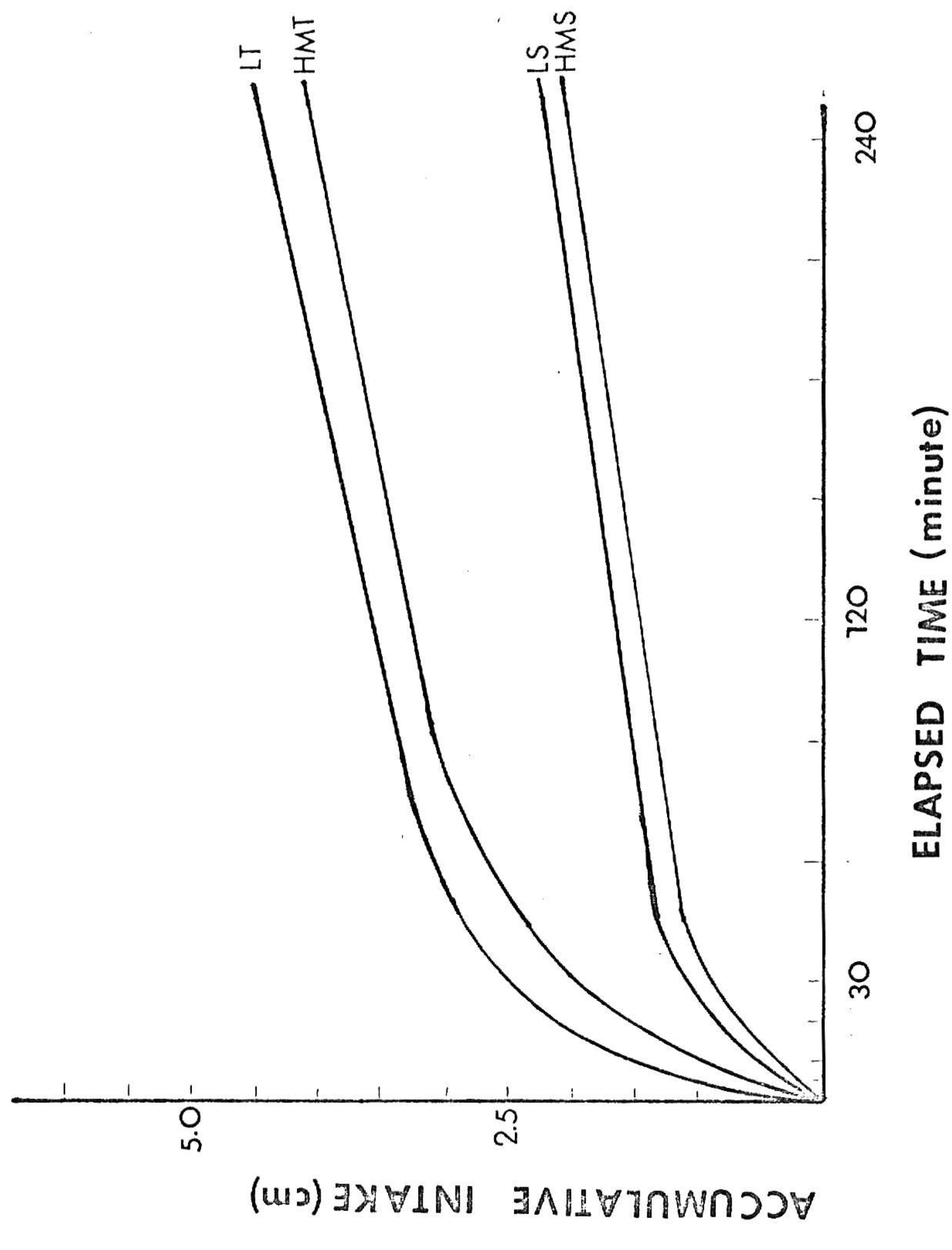
ACCUMULATIVE INTAKE (cm)
5.0
2.5
ELAPSED TIME (minute)
30
120
240
LT
HMT
LS
HMS

Fig. 2. Accumulative water intake in cm for a topsoil with three infiltration rings ($T_1$, $T_2$, and $T_3$) and a subsoil with four infiltration rings ($S_1$, $S_2$, $S_3$, and $S_4$).

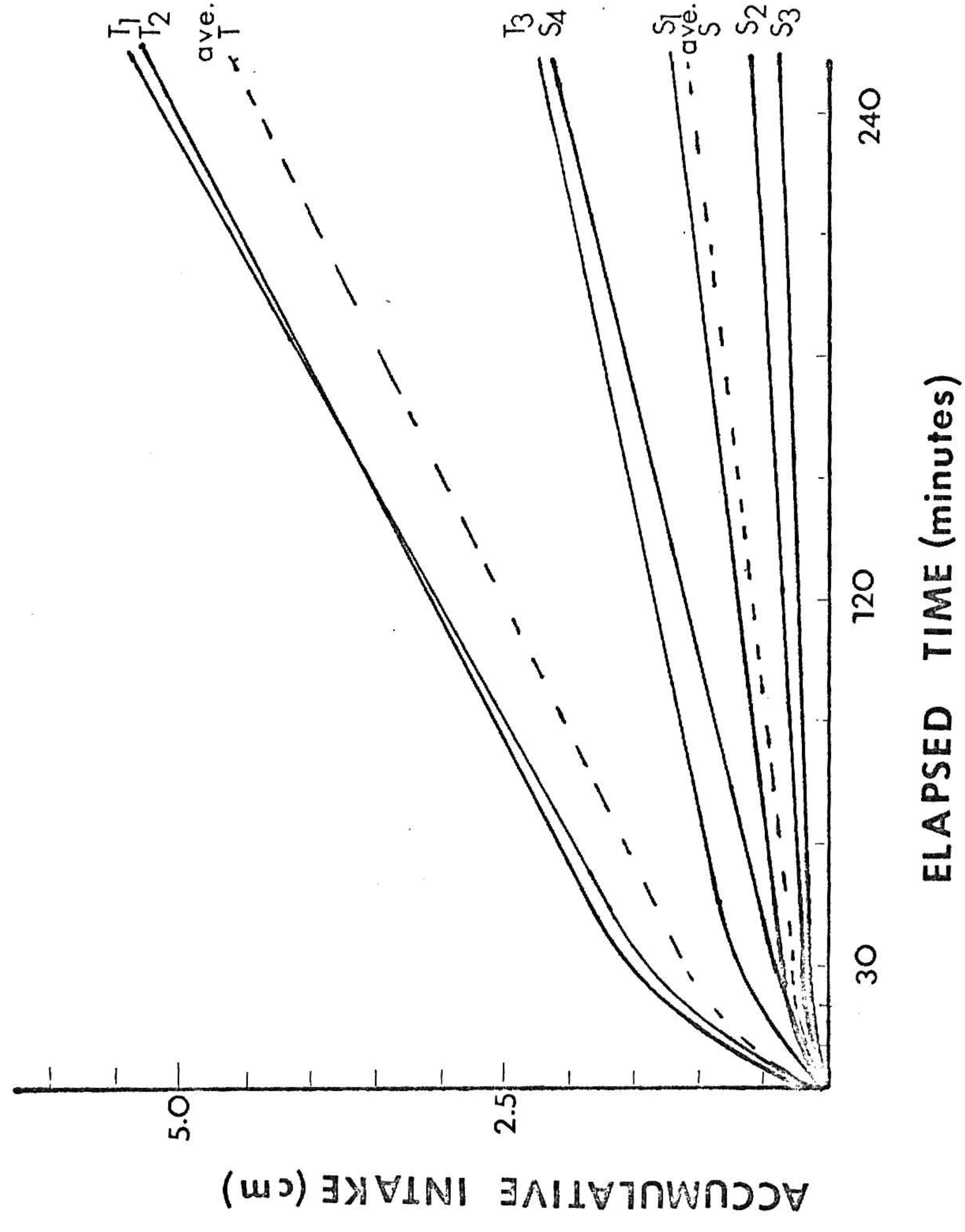
ACCUMULATIVE INTAKE (cm)
5.0
2.5
30
120
240
ELAPSED TIME (minutes)
T1
T2
ave. T
T3
S4
S1
ave. S
S2
S3

Table 7. Water intake rates in cm/hr during time intervals on a low subsoil plot, a high manure subsoil plot, a low topsoil plot, and a high manure topsoil plot.

| Elapsed time | Fertility Treatments | | | |
|---|---|---|---|---|
| | Low Subsoil | High Manure Subsoil | Low Topsoil | High Manure Topsoil |
| Minutes | cm/hr | | | |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 5 | 6.12 | 4.56 | 15.84 | 10.68 |
| 10 | 4.56 | 3.84 | 11.46 | 7.62 |
| 20 | 3.06 | 2.28 | 6.87 | 4.56 |
| 30 | 2.28 | 1.78 | 5.34 | 4.06 |
| 45 | 2.22 | 1.27 | 5.11 | 4.22 |
| 60 | 1.40 | 1.27 | 3.17 | 2.67 |
| 90 | 1.02 | .97 | 2.39 | 2.13 |
| 120 | .89 | .80 | 1.97 | 1.65 |
| 180 | .97 | .59 | 1.38 | 1.05 |
| 240 | .57 | .53 | 1.14 | 1.05 |

Table 8. Water intake rates in cm/hr during time intervals on a high manure topsoil plot and a high manure subsoil plot.

| Elapsed time | High Manure Topsoil | | | | High Manure Subsoil | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ * | $T_2$ | $T_3$ | | $S_1$ + | $S_2$ | $S_3$ | $S_4$ | |
| Minutes | | cm/hr | | Avg. | | | cm/hr | | Avg. |
| 5 | 6.10 | 7.62 | 4.57 | 6.10 | 3.05 | 0.00 | 0.00 | 0.00 | .76 |
| 10 | 5.64 | 5.33 | 2.59 | 4.57 | 1.52 | .76 | .76 | .76 | .97 |
| 20 | 3.81 | 3.81 | 1.91 | 3.20 | .99 | .38 | .38 | .76 | .64 |
| 30 | 3.30 | 3.30 | 1.37 | 2.64 | .76 | .25 | .25 | .51 | .46 |
| 45 | 2.51 | 2.59 | 1.19 | 2.08 | .58 | .23 | .18 | .69 | .94 |
| 60 | 2.29 | 2.21 | 1.02 | 1.78 | .43 | .25 | .13 | .51 | .33 |
| 90 | 1.88 | 1.96 | .86 | 1.57 | .38 | .18 | .08 | .69 | .33 |
| 120 | 1.70 | 1.70 | .76 | 1.40 | .38 | .18 | .08 | .69 | .33 |
| 180 | 1.50 | 1.47 | .58 | 1.19 | .33 | .18 | .13 | .58 | .30 |
| 240 | 1.40 | 1.40 | .56 | 1.12 | .30 | .15 | .10 | .53 | .28 |

* $T_1$, $T_2$, and $T_3$ represent the three cylinders placed on the topsoil plot.

\+ $S_1$, $S_2$, $S_3$, and $S_4$ represent the four cylinders placed on the subsoil plot.

Runoff was included as consumptive use for each plot since it was not measured. The average consumptive use during the period of measurement was 31.30 cm on the topsoil and 29.56 cm on the subsoil.

The ring infiltrometer study showed that the accumulative intake and the intake rate on the silty clay loam topsoil was considerably greater than the accumulative intake and the intake rate on the silty clay subsoil (Figs. 1 and 2; Tables 7 and 8).

The subsoil of Smolan is not considered very productive because of its heavy texture (about 40% clay). Soil tests on samples taken after harvest in 1971 indicated that the fertility of the topsoil was greater than the fertility of the subsoil (Table 29). The pH was slightly lower on the topsoil than on the subsoil. The subsoil plots, except for the high manure treatment, had less organic matter than the topsoil plots. This is due to the removal of organic matter with the excavation process. Manure additions only partially account for the high organic matter content of the high manure subsoil treatment. There is no known explanation for these values from the high manure treatment. The amount of available phosphorus was nearly twice as great in the topsoil as that in the subsoil. Since phosphorus is immobile, much of it was removed during excavation. The amount of residual phosphorus varied with the amount applied in each treatment. It can be concluded that the addition of chemical fertilizers and manure raised the fertility of both topsoil and subsoil.

## DISCUSSION

Yields of wheat in 1969 were about half as great as wheat yields in 1971. Yields of grain from the subsoil in 1969 were equal to the yields of grain from the topsoil, but in 1971 the yields of grain from the subsoil were not equal to the yield of grain from the topsoil under any of the treatments used. This wide variation in yields can be attributed to several factors. There was a year of fallow between the two crops of wheat. The fallow may have resulted in an accumulation of nitrates and the storage of water in the soil profile. Rainfall distribution in 1969 indicated the possibility of moisture stress during a critical period in the growing season. Low test weights which probably resulted from a late seeding date, a late spring season, and stem rust were important factors which influenced yields in 1969. The 1971 wheat crop was never under moisture stress during the growing season. It should be kept in mind that residual fertilizer from a sorghum crop which was planted and abandoned during the summer of 1971 was available to the 1971 wheat crop. Since the sorghum crop received higher fertilizer rates than did the 1969 wheat crop, there was more fertilizer available to the 1971 wheat crop (Table 2).

The test weight of grain from the 1969 wheat crop was much lower than the test weight of grain from the 1971 wheat crop. The 1971 wheat crop had a favorable growing season and there was no evidence of stem rust. The reason for lower test weights on topsoil than on subsoil from the 1971 crop is not known. The test weights showed no response to fertility treatments in neither 1969 nor in 1971.

The high protein content of the grain from the topsoil and from the high manure subsoil treatment was apparently related to the organic matter content of the soil (Table 29). The high fertility treatments and the high manure treatments included large amounts of nitrogen which is important in the synthesis of protein. The high, medium and low treatments of the subsoil had low natural fertility and low organic matter contents; therefore, they produced grain with low protein content.

The number of plants that emerged per 15 dm of row on subsoil plots was greater than those that emerged on the topsoil plots. The difference in emergence was associated with the low bulk density of the subsoil plots (Table 6). The subsoil was not expected to have the lowest bulk density but this can possibly be attributed to the cloddiness of the fine textured B horizon.

At harvest the number of heads per 15 dm of row was greater on the topsoil plots than on the subsoil plots. The greater number of heads on the topsoil plots compared to those on the subsoil may be attributed to greater availability of nutrients on the topsoil plots.

A difference in total consumptive use of water was expected since a ring infiltrometer study (Figs. 1 and 2) revealed a difference in the intake rates on the topsoil and the subsoil. The infiltration rate of the silty clay loam topsoil was greater than the infiltration rate of the silty clay subsoil. This difference in infiltration was speculated to be due to the greater amount of porosity in the topsoil as compared to the finer textured subsoil soon after harvest in 1971.

The similarity in the consumptive use of water by wheat grown on topsoil and subsoil can possibly be attributed to the one year fallow period and runoff; however, since there were not many intense rains during the growing season which produced runoff, the effect of runoff is questionable. The average consumptive use of water per day on topsoil plots was .47 cm and the average consumptive use of water on the subsoil was .46 cm. This amount is considered reasonable for states in the Great Plains.

The yield results obtained in 1969 tended to support observations made by other investigators that nitrogen and phosphorus limited production on the subsoil (5, 8, 13, 24, 33); however, 1971 data suggest that factors other than a deficiency of nitrogen and phosphorus limited production on the subsoil plots. The failure of yields on the subsoil to equal yields on the topsoil under all fertility treatments employed support this conclusion. The two years data from this study support the suggestion of Englestad, Shrader, and Dumenil (11) that "The ability of fertilizer and manure to supplement topsoil removal depends on climate".

In the future consideration might be given to the role of minor elements in causing yield differences between topsoil and subsoil plots. There also should be check plots included in the study. The check plots could be used to compare the changes in the fertility of the soil with time.

More measurements of physical properties should be taken to determine what part physical properties play in causing low yields on the subsoil plots. The measurements should include aggregate stability, particle size analysis, available water holding capacity, and runoff.

With measurements taken in this study many of the factors which may have caused a reduction in yields on the subsoil could not be evaluated.

## CONCLUSIONS

1. Under the climatic conditions of 1969, wheat grown on subsoil showed greater response to fertility treatments than that grown on topsoil. Average yields of grain from the subsoil were equal to average yields from the topsoil.

2. Under the climatic conditions of 1971, wheat grown on subsoil and topsoil showed no significant response to fertility treatments. Yields from the subsoil were less than yields from the topsoil.

3. Chemical fertilizers plus manure can cause yields from subsoil to equal yields from topsoil in some years depending on the climatic conditions.

4. The intake rate of water was greater on topsoil plots than on subsoil plots.

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# APPENDIX

Table 9. The effect of fertility treatments on yield in kg/ha from topsoil (T) and subsoil (S) in 1969.

| Treatments | Replications | | | | | |
|---|---|---|---|---|---|---|
| | I | | II | | III | |
| | T | S | T | S | T | S |
| Low | 1780.80 | 1223.04 | 1780.80 | 1370.88 | 1921.92 | 1632.96 |
| Medium | 1525.44 | 1491.84 | 2513.28 | 1948.80 | 1921.92 | 1780.80 |
| High | 1538.88 | 1344.00 | 1599.36 | 2103.36 | 1632.96 | 2472.96 |
| High Manure | 1538.88 | 1612.80 | 2318.40 | 2304.96 | 2163.84 | 2560.32 |

Table 10. Analysis of variance summary of the effect of fertility treatments on yields in 1969.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 1253147.4060 | 626573.7032 | | |
| Topsoil-Subsoil | 1 | 1808.1423 | 1808.1423 | 0.03 | Ns |
| Treatments | 3 | 667235.6811 | 222411.8937 | 4.06 | * |
| Treatments x Topsoil-Subsoil | 3 | 568112.5416 | 189370.8472 | 3.46 | * |
| Error | 14 | 766873.6264 | 54776.6876 | | |
| Total | 23 | 325717.7255 | | | |

*Significant at the 0.05 level
Ns not significant

Table 11. Effect of fertility treatments on test weight in kg/hl from topsoil (T) and subsoil (S) in 1969.

| Treatments | Replications | | | | | |
|---|---|---|---|---|---|---|
| | I | | II | | III | |
| | T | S | T | S | T | S |
| Low | 72.87 | 73.52 | 73.52 | 76.48 | 73.13 | 77.64 |
| Medium | 71.84 | 75.84 | 73.26 | 77.64 | 72.74 | 76.48 |
| High | 73.13 | 73.77 | 71.45 | 76.10 | 68.42 | 77.64 |
| High Manure | 72.87 | 72.10 | 71.84 | 75.06 | 71.32 | 76.10 |

Table 12. Analysis of variance summary of the effect of fertility treatments on test weight in 1969.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 3.8634 | 1.9317 | | |
| Topsoil-Subsoil | 1 | 60.1923 | 60.1923 | 18.94 | * |
| Treatments | 3 | 15.5340 | 5.1780 | 1.63 | Ns |
| Treatments x Topsoil-Subsoil | 3 | 2.5137 | .8379 | 0.26 | Ns |
| Error | 14 | 44.4976 | 3.1784 | | |
| Total | 23 | 126.6010 | | | |

Table 13. The effect of fertility treatments on yield in kg/ha from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications I T | I S | II T | II S | III T | III S |
|---|---|---|---|---|---|---|
| Low | 4273.92 | 4294.08 | 4368.00 | 3951.36 | 3890.88 | 1989.12 |
| Medium | 3796.80 | 3763.20 | 4730.88 | 2956.80 | 3225.60 | 3830.40 |
| High | 4751.04 | 4273.92 | 4872.00 | 4287.36 | 4435.20 | 3689.28 |
| High Manure | 4663.68 | 4589.76 | 4148.93 | 3984.96 | 4663.68 | 3116.16 |

Table 14. Analysis of variance summary of the effect of fertility treatments on yields in 1971.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 1754143.7276 | 877071.8638 | | |
| Topsoil-Subsoil | 1 | 1814473.9952 | 1814473.9952 | 6.29 | * |
| Treatments | 3 | 2032534.4256 | 677511.4752 | 2.35 | Ns |
| Treatments x Topsoil-Subsoil | 3 | 169073.0496 | 56357.6832 | 0.20 | Ns |
| Error | 14 | 4036968.5846 | 288354.8989 | | |
| Total | 23 | 9807193.7826 | | | |

Table 15. Effect of fertility treatments on test weight in kg/hl from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications I T | I S | II T | II S | III T | III S |
|---|---|---|---|---|---|---|
| Low | 82.03 | 81.13 | 82.16 | 80.87 | 82.42 | 82.16 |
| Medium | 81.90 | 81.38 | 82.16 | 82.03 | 82.16 | 81.90 |
| High | 80.93 | 81.64 | 81.64 | 82.16 | 81.77 | 81.84 |
| High Manure | 81.50 | 82.03 | 81.38 | 81.90 | 81.90 | 81.64 |

Table 16. Analysis of variance summary of the effects of fertility treatments on test weight in 1971.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 0.6514 | 0.3257 | | |
| Topsoil-Subsoil | 1 | 0.0690 | 0.0690 | 0.66 | Ns |
| Treatments | 3 | 0.2490 | 0.0830 | 0.79 | Ns |
| Treatments x Topsoil-Subsoil | 3 | 1.4412 | 0.4804 | 4.57 | * |
| Error | 14 | 1.4714 | 0.1051 | | |
| Total | 23 | 3.8820 | | | |

Table 17. Effect of fertility treatments on protein content in grain from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications | | | | | |
|---|---|---|---|---|---|---|
| | I | | II | | III | |
| | T | S | T | S | T | S |
| Low | 14.25 | 11.69 | 14.14 | 10.83 | 13.79 | 12.88 |
| Medium | 14.65 | 12.03 | 14.42 | 13.05 | 13.62 | 12.37 |
| High | 13.91 | 11.74 | 14.71 | 12.88 | 14.25 | 12.31 |
| High Manure | 14.65 | 14.71 | 14.19 | 14.08 | 14.42 | 14.59 |

Table 18. Analysis of variance summary of the effects of fertility treatments on protein content of grain in 1971.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 0.0225 | 0.0112 | | |
| Topsoil-Subsoil | 1 | 13.8624 | 13.8624 | 35.15 | * |
| Treatments | 3 | 8.0945 | 2.6981 | 6.84 | * |
| Treatments x Topsoil-Subsoil | 3 | 5.1889 | 1.7296 | 4.39 | * |
| Error | 14 | 5.5207 | 0.3943 | | |
| Total | 23 | 32.6892 | | | |

Table 19. Effect of fertility treatments on plant emergence per 15 dm of row from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications | | | | | |
|---|---|---|---|---|---|---|
| | I | | II | | III | |
| | T | S | T | S | T | S |
| Low | 74 | 97 | 95 | 99 | 84 | 105 |
| Medium | 71 | 97 | 66 | 88 | 104 | 96 |
| High | 92 | 110 | 70 | 91 | 101 | 94 |
| High Manure | 67 | 87 | 74 | 81 | 103 | 96 |

Table 20. Analysis of variance summary of the effect of fertility treatments on plant emergence in 1971.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 1296.7500 | 648.3750 | | |
| Topsoil-Subsoil | 1 | 1176.0000 | 1176.0000 | 17.25 | * |
| Treatments | 3 | 297.8333 | 99.2777 | 1.46 | Ns |
| Treatments x Topsoil-Subsoil | 3 | 177.3333 | 59.1111 | .87 | Ns |
| Error | 14 | 954.5833 | 68.1845 | | |
| Total | 23 | 3902.5000 | | | |

Table 21. Effect of fertility treatments on number of heads per 15 dm of row from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications I T | I S | II T | II S | III T | III S |
|---|---|---|---|---|---|---|
| Low | 291 | 230 | 274 | 232 | 177 | 150 |
| Medium | 306 | 228 | 338 | 227 | 234 | 217 |
| High | 331 | 314 | 294 | 289 | 246 | 280 |
| High Manure | 313 | 272 | 319 | 313 | 324 | 291 |

Table 22. Analysis of variance summary of the effect of fertility treatments on number of heads in 1971.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 11193.5833 | 5596.7916 | | |
| Topsoil-Subsoil | 1 | 6800.6666 | 6800.6666 | 8.17 | * |
| Treatments | 3 | 23088.5000 | 7696.1666 | 9.25 | * |
| Treatments x Topsoil-Subsoil | 3 | 4179.3333 | 1393.1111 | 1.67 | Ns |
| Error | 14 | 11651.7500 | 832.2678 | | |
| Total | 23 | 56913.8333 | | | |

Table 23. Effect of fertility treatments on number of tillers from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications | | | | | |
|---|---|---|---|---|---|---|
| | I | | II | | III | |
| | T | S | T | S | T | S |
| Low | 3.93 | 2.37 | 2.88 | 2.34 | 2.11 | 1.43 |
| Medium | 4.31 | 2.79 | 3.49 | 2.18 | 3.55 | 2.26 |
| High | 3.60 | 3.45 | 2.67 | 2.86 | 3.51 | 2.98 |
| High Manure | 4.67 | 3.36 | 3.67 | 3.04 | 4.38 | 3.03 |

Table 24. Analysis of variance summary of the effects of fertility treatments on number of tillers in 1971

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 2 | 2.1631 | 1.0815 | | |
| Topsoil-Subsoil | 1 | 4.9223 | 4.9223 | 35.74 | * |
| Treatments | 3 | 4.2194 | 1.4064 | 10.21 | * |
| Treatments x Topsoil-Subsoil | 3 | 1.2996 | 0.4332 | 3.15 | Ns |
| Error | 14 | 1.9279 | 0.1377 | | |
| Total | 23 | 14.5324 | | | |

Table 25. Effect of fertility treatments on consumptive use of water in cm from topsoil (T) and subsoil (S) in 1971.

| Treatments | Replications | | | |
|---|---|---|---|---|
| | II | | III | |
| | T | S | T | S |
| Low | 27.79 | 30.45 | 29.90 | 27.56 |
| Medium | 32.13 | 31.09 | 30.12 | 29.51 |
| High | 28.78 | 30.30 | 24.26 | 30.94 |
| High Manure | 34.57 | 30.61 | 23.57 | 28.50 |

Table 26. Analysis of variance summary of the effect of fertility treatments on consumptive use of water in 1971.

| Source | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Replications | 1 | 22.1345 | 22.1345 | | |
| Topsoil-Subsoil | 1 | 1.7608 | 1.7608 | 0.22 | Ns |
| Treatments | 3 | 14.1312 | 4.7104 | 0.58 | Ns |
| Treatments x Topsoil-Subsoil | 3 | 17.1963 | 5.7321 | 0.71 | Ns |
| Error | 7 | 56.5054 | 8.0722 | | |
| Total | 15 | 111.7282 | | | |

Table 27. Consumptive use of water between April 22 and June 24, 1971.

| Plot | Initial Water in Soil | Final Water in Soil | Total Rainfall | Consumptive Use |
|---|---|---|---|---|
| | ---------- | ---------- cm | ---------- | ---------- |
| 9 | 55.35 | 52.30 | 27.41 | 30.45 |
| 10 | 55.50 | 48.34 | 27.41 | 34.57 |
| 11 | 53.57 | 52.20 | 27.41 | 28.74 |
| 12 | 55.14 | 50.17 | 27.41 | 32.13 |
| 13 | 52.35 | 51.97 | 27.41 | 27.79 |
| 14 | 51.44 | 48.36 | 27.23 | 30.30 |
| 15 | 48.29 | 44.91 | 27.23 | 30.61 |
| 16 | 52.83 | 48.90 | 27.41 | 31.09 |
| 17 | 52.10 | 55.93 | 27.41 | 23.57 |
| 18 | 52.02 | 54.99 | 27.41 | 24.26 |
| 19 | 54.33 | 52.04 | 27.41 | 29.51 |
| 20 | 53.09 | 54.41 | 27.41 | 29.90 |
| 21 | 49.02 | 45.31 | 27.23 | 30.94 |
| 22 | 53.80 | 53.47 | 27.23 | 27.56 |
| 23 | 48.46 | 47.19 | 27.23 | 28.50 |
| 24 | 48.49 | 45.59 | 27.23 | 30.12 |

The equation used to calculate the consumptive use of water is given below and data used in the calculations are given above.

Consumptive use of $H_2O$ = initial $H_2O$ - final $H_2O$ + total rainfall

Note: The difference in rainfall reflects a one day difference in dates measurements were taken.

Computation of linear regression equation used in determining the surface depth of water.

The data from Table 28 were used to prepare an equation for converting the neutron probe readings to percent water by volume. The percent water by volume and the ratio of the count to the standard count for each 15.24 cm increment to a depth of 183 cm at each calibration site were used to calculate a linear regression equation. The equation was of the form, Y = A + BX. In the equation Y is the percent water by volume and X is the ratio of the count to the standard count.

The results of the calculation were:

A = 5.67136

B = 16.74300

Deviation about regression 3.587

Variance of B = 0.52152

Variance of A = 0.94024

F = 637.51709

Correlation coefficient = 0.96475

The formula for calculating the percent water by volume is:

$$\text{percent water by volume} = 5.67 + 16.74\left(\frac{\text{count}}{\text{standard count}}\right).$$

The formula for the equivalent surface depth of water is:

$$\text{surface depth} = \frac{\%\ H_2O\ \text{by vol.}}{100}\ (\text{depth});$$

therefore, for 15.24 cm (6 in.) intervals the formula is:

$$\text{surface cm} = 5.67 + 16.74\left(\frac{\text{count}}{\text{standard count}}\right)(.1524).$$

Table 28. Calibration data for the moisture curve taken at two dates.

May 6, 1971

| Depth | Bulk Density | Percent water by weight * | Percent water by weight + | Percent water by volume * | Percent water by volume + | Count/standard * | Count/standard + |
|---|---|---|---|---|---|---|---|
| cm | g/cm$^3$ | | | | | | |
| 0-15 | 1.36 | 24.77 | 21.95 | 33.69 | 29.85 | 1.6945 | 1.4910 |
| 15-30 | 1.43 | 27.18 | 26.29 | 38.87 | 37.59 | 1.8936 | 1.8392 |
| 30-46 | 1.44 | 27.68 | 24.37 | 39.86 | 35.09 | 1.8365 | 1.7505 |
| 46-61 | 1.49 | 25.18 | 20.99 | 37.52 | 31.28 | 1.7558 | 1.6732 |
| 61-76 | 1.51 | 23.98 | 22.14 | 36.21 | 33.43 | 1.7220 | 1.6032 |
| 76-91 | 1.51 | 23.09 | 21.88 | 34.87 | 33.04 | 1.7513 | 1.6156 |
| 91-107 | 1.48 | 22.95 | 21.49 | 33.97 | 31.81 | 1.7420 | 1.6265 |
| 107-122 | 1.48 | 22.35 | 21.76 | 33.08 | 32.20 | 1.6916 | 1.6710 |
| 122-137 | 1.47 | 21.09 | 21.42 | 31.00 | 31.49 | 1.5316 | 1.6683 |
| 137-152 | 1.47 | 20.42 | 18.01 | 30.02 | 26.47 | 1.4930 | 1.3845 |
| 152-168 | 1.48 | 19.58 | 13.75 | 28.98 | 20.35 | 1.5040 | 1.1145 |

* Site number 1, average of four determinations

+ Site number 2, average of four determinations

Table 28 (contd). Calibration data for the moisture curve taken at two dates

| | | Aug. 26, 1971 | | | | | |
|---|---|---|---|---|---|---|---|
| Depth | Bulk Density | Percent water by weight | | Percent water by volume | | Count / standard | |
| | | * | + | * | + | * | + |
| cm | $g/cm^3$ | | | | | | |
| 0-15 | 1.36 | 10.45 | 8.76 | 14.21 | 11.94 | 0.6698 | 0.5510 |
| 15-30 | 1.43 | 16.22 | 14.35 | 23.19 | 20.52 | 1.0574 | 1.0695 |
| 30-46 | 1.44 | 17.48 | 17.29 | 25.17 | 24.90 | 1.0549 | 1.0054 |
| 46-61 | 1.49 | 16.62 | 14.37 | 24.76 | 21.41 | 1.0222 | 0.8924 |
| 61-76 | 1.51 | 15.54 | 14.16 | 23.47 | 21.38 | 0.9147 | 0.8189 |
| 76-91 | 1.51 | 14.96 | 14.04 | 22.59 | 21.20 | 0.8281 | 0.8051 |
| 91-107 | 1.48 | 14.32 | 13.46 | 21.19 | 19.92 | 0.8853 | 0.8151 |
| 107-122 | 1.48 | 14.23 | 13.53 | 21.06 | 20.02 | 0.9161 | 0.8184 |
| 122-137 | 1.47 | 14.54 | 13.41 | 21.37 | 19.91 | 0.9383 | 0.9363 |
| 137-152 | 1.47 | 11.96 | 15.31 | 17.58 | 22.24 | 0.8557 | 0.8640 |
| 152-168 | 1.48 | | | | | | |

* Site number 1, average of four determinations

+ Site number 2, average of four determinations

Table 29. Soil test data

| | pH | Organic Matter | Available Phosphorus | Exchangeable Potassium | $NH_4$-N 0-30cm | $NH_4$-N 30-60cm | $NO_3$-N 0-30cm | $NO_3$-N 30-60cm |
|---|---|---|---|---|---|---|---|---|
| | | percent | kg/ha | | ppm | | | |
| High Manure Topsoil | 5.3 | 2.4 | 126.6 | 795 | 17.1 | 8.2 | 16.7 | 7.0 |
| High Topsoil | 5.4 | 2.3 | 89.1 | 586 | 8.5 | 7.2 | 5.6 | 2.0 |
| Med. Topsoil | 5.4 | 2.3 | 58.2 | 567 | 6.5 | 6.0 | 7.2 | 3.3 |
| Low Topsoil | 5.5 | 2.3 | 45.9 | 582 | 8.0 | 7.6 | 5.1 | 2.3 |
| High Manure Subsoil | 5.7 | 2.7 | 76.2 | 713 | 10.7 | 5.3 | 15.0 | 4.5 |
| High Subsoil | 5.7 | 1.7 | 58.2 | 564 | 6.8 | 6.2 | 2.0 | 1.2 |
| Med. Subsoil | 5.8 | 1.9 | 32.1 | 564 | 6.6 | 6.1 | 2.8 | 2.1 |
| Low Subsoil | 5.8 | 2.0 | 17.6 | 564 | 6.9 | 7.0 | 2.3 | 2.8 |

Table 30. Description of soil profile.

Soil Profile: Smolan Silty Clay Loam[4/]

Smolan soils are found on high terraces and uplands. Slope gradients are mostly between 1 and 8%. These soils were formed in old silty sediments believed to be loess that is older and more weathered than the Peorian loess. The climate under which the soil formed is subhumid; mean annual precipitation ranges from about 61 to 71 cm. Thornthwaite's annual P-E index is 40 to 54, and the mean air temperature is about 51% to 57% (29).

$A_{1p}$ 0-8cm Grayish brown (10YR 5/1.5) dry, very dark gray (10YR 2.5/1) moist, light silty clay loam; moderate very fine granular structure; friable, slightly hard; noncalcareous, acid; abrupt boundary; 8 to 20cm thick.

$A_1$ 8-20cm Dry grayish brown (10YR 4/1.5) dry, very dark gray (10YR 2.5/1) moist, silty clay loam; moderate very fine subangular blocky structure; firm, hard; noncalcareous; acid; clear boundary; 10 to 20cm thick.

AB 20-36cm Dark gray (10YR 4/1) dry, very dark gray (10YR 3/1) moist, silty clay loam; strong very fine subangular blocky structure; firm, extremely hard; noncalcareous, acid; clear boundary; 10 to 20cm thick.

$B_{21}$ 36-76 cm Grayish brown (10YR 5/2) dry, very dark grayish brown (10YR 3/2) moist, silty clay; moderate medium blocky structure; very firm, very hard; noncalcareous, acid; clear boundary; 36 to 51 cm thick.

$B_{22}$ 76-107cm Brown and dark brown (10YR 5/3 and 4/3), dry, dark brown (10YR 4/3) moist, silty clay; weak blocky structure; very firm, very hard; noncalcareous, acid; clear boundary; 25 to 31 cm thick.

$B_3$ 107-132cm Pale brown and yellowish brown (10YR 6/3, 5/4) dry, brown (10YR 5/3, 7.5YR 4/4) moist; many fine distinct mottles; silty clay; massive structure; very firm extremely hard, noncalcareous, acid; clear boundary; 20 to 31 cm thick.

C 132-152cm Pale brown and yellowish red (10YR 6/3, 5YR 4/7) dry, brown (7.5YR 5/4, 4/4) moist, silty clay; many fine distinct mottles; massive structure; firm extremely hard; noncalcareous, acid.

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[4/] Site described on the Kansas State University Agronomy Research Farm by Dr. O.W. Bidwell, 1956.

# RESPONSE OF WHEAT TO FERTILIZERS ON TOPSOIL AND SUBSOIL

by

MAJOR D. MAYS

A.M. & N. College
Arkansas, 1968

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The surface layer of soil is generally more fertile than the subsurface layers. Because of soil erosion, land leveling and other activities involving land grading, some areas are left with subsurface layers exposed. Under these conditions it is important to determine if crop production on the subsoil can be made to equal production on the topsoil; therefore, the purpose of this study was to determine the best method or combination of methods for improving production on the exposed subsoil.

In this study, the term topsoil referred to the surface layer with maximum organic matter accumulation. Subsoil referred to soil below 20 centimeters depth.

In field studies two crops of wheat (1969 and 1971) were grown on Smolan silty clay loam soil. Four fertility treatments were applied to topsoil plots and to subsoil plots. The fertility treatments contained three different levels of nitrogen and phosphorus fertilizer and one treatment contained nitrogen and phosphorus fertilizers plus manure.

Results indicated that chemical fertilizers and chemical fertilizers plus manure can cause production from the subsoil to equal that from the topsoil in some years depending on climatic conditions. Under the climatic conditions of 1969, yields from the subsoil were equal to yields from the topsoil, but in 1971, yields from the subsoil were not equal to yields from the topsoil regardless of fertility treatments. The infiltration rate on the topsoil was much greater than the infiltration rate on the subsoil.

Factors other than the availability of nitrogen and phosphorus were probably the cause of the large differences in yields in 1971 from topsoil and subsoil. Other nutrients and physical properties of the soil should be investigated.