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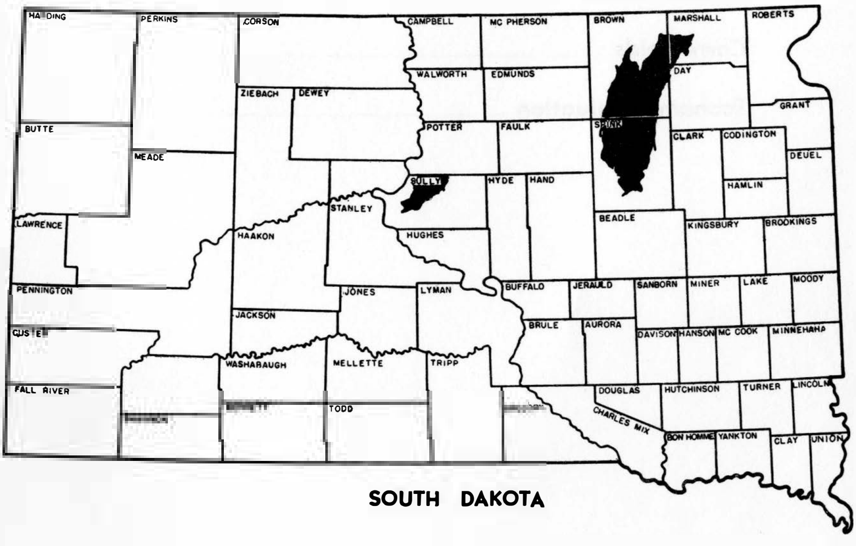

AGRONOMY DEPARTMENT
AGRICULTURAL EXPERIMENT STATION
SOUTH DAKOTA STATE COLLEGE, BROOKINGS

Contents

FERTILIZING IRRIGATED ROTATIONS

in the Proposed Oahe Irrigation Area[1]

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Some results of an experiment conducted from 1953 through 1962 at the Redfield Development Farm are compiled in this bulletin. The experiment evaluated various fertilizer rates and times of application in two irrigated rotations.

Yield results are taken from 1957, 1958, 1960, and 1962. The information gathered prior to 1957 is omitted because one of the rotations was still in the first cycle. Data from 1959 are excluded because insufficient quantities of irrigation water produced uncommonly low crop yields. The 1961 data are discarded since technological difficulties abnormally affected crop yield measurements. Discarding these data is justified as these problems likely would not be encountered by farmers who eventually will irrigate similar soils.

SOILS

The experiment was conducted on Beotia silt loam, level (0-1% slope) and Great Bend silt loam, level (0-1% slope) soils. These soils are described in South Dakota State College Experiment Station Bulletin 439, "Soil Survey of Spink County, South Dakota." In general, both are deep, friable soils of good tilth which occur to a limited extent along and near the stream channels in the Lake Dakota plain.

CLIMATIC CONDITIONS

The 1957 growing season was cool and had 5 inches above average rainfall. About one-half of this 5 inches fell in May. In 1958, temperatures during May, June, and July were farthest from average. The average mean temperature for May was relatively warm, while the average temperatures for June and July were cool. Total rainfall during the 1958 growing season was almost 5 inches below average. This deficit in rainfall was recorded from June through October.

[1]A report on research conducted by South Dakota Agricultural Experiment Station at the Redfield Irrigation Development Farm and Experimental Substation, in cooperation with the U. S. Bureau of Reclamation and the Agricultural Research Service, USDA.

The 1960 and 1962 growing seasons were similar. Average monthly mean temperatures were below average almost every month, and rainfall was above average most months. The departures from average monthly temperatures ranged from –0.9°F. to –4.5°F in 1960. In 1962 the departures ranged from +1.0°F. to –6.2°F.

Total precipitation for the 1960 growing season was 18.86 inches, approximately 4.5 inches above average. Total precipitation for the 1962 growing season exceeded 20 inches, over 6 inches above average. Nearly 16.5 inches were received during May, June, and July. Excessive rainfall in 1962 caused high water table conditions which hampered normal experimental operations and resulted in stand reductions on the alfalfa plots.

Rainfall and temperature conditioned the amounts of supplemental irrigation applied in various seasons. Soil moisture was thus essentially removed as a major variable in crop performance, and accordingly interactions involving soil moisture and treatments are felt to be reduced.

EXPERIMENTAL DESIGN AND RESULTS

A barley-alfalfa-alfalfa-corn-corn rotation and a barley-corn-corn rotation were used in this experiment. The first rotation was selected be-

Table 1. Fertilizer Applications Made to Crops in Two Irrigated Rotations at Redfield, and Total Amounts To Be Used in 5- and 3-year Rotations*

	Fertilizer Treatment Numbers									
	1	2	3	4	5	6	7	8	9	10
Rotation A										
Barley	------	40+0	0+110	0+110	0+110	20+110	40+110	60+110	40+55	40+35
Alfalfa (1)	------	------	------	------	------	------	------	------	------	------
Alfalfa (2)	------	------	------	------	------	------	------	------	------	------
Corn (1)	------	80+0	------	------	120+0	40+0	80+0	120+0	80+0	80+10
Corn (2)	------	120+0	------	120+0	------	60+0	120+0	180+0	120+0	120+10
Total (5 yrs.)	**0-0**	**240+0**	**0+110**	**120+110**	**120+110**	**120+110**	**240+110**	**360+110**	**240+55**	**240+55**
Rotation B										
Barley	------	40+0	0+66	0+66	0+66	20+66	40+66	60+66	40+33	40+11
Corn (1)	------	80+0	------	------	120+0	40+0	80+0	120+0	80+0	80+11
Corn (2)	------	120+0	------	120+0	------	60+0	120+0	180+0	120+0	120+11
Total (3 yrs.)	**0-0**	**240+0**	**0+66**	**120+66**	**120+66**	**120+66**	**240+66**	**360+66**	**240+33**	**240+33**

*No potassium is applied in the experiments. Figures represent pounds of N and P per acre, respectively (P x 2.29 = P_2O_5).

cause it is adaptable to livestock feeding programs, and the second rotation was adopted since it is applicable to cash-grain types of farming.

The term, "crop year," was assigned to each crop in the year it occurred in a given rotation. Thus, there were eight crop years in the two rotations. These eight crop years were present in the experiment each year and occupied an equal amount of land. Ten fertilizer treatments were superimposed on each of the crop years and the experiment was replicated three times.

The rotations and the fertilizer treatments, which contained varying rates of nitrogen and phosphorus, are listed in table 1. Fertilizers were applied to the crop years in various increments of the total fertilizer treatment and were incorporated in the soil each spring as ammonium nitrate and treble superphosphate. The total fertilizer treatment for a given cropping sequence was of primary concern in evaluating this experiment. Comparisons of different individual treatments with the same total treatment have been made in some cases.

Average yields for the various crops in the two rotations as influenced by the 10 fertilizer treatments are shown in table 2. Some of the more important relationships between crop yields and fertilizer treatments are illustrated in figures 1-5.

BARLEY YIELDS

Table 2 demonstrates few differences among barley yields for the various total fertilizer treatments in Rotation A (barley-alfalfa-alfalfa-corn-corn). There are no significant differences among barley yields under treatments 4 through 10. Most of the differences among the barley yields can be seen in figure 1. This figure indicates that phosphorus alone increased the barley yield by approximately 4 bushels (difference between treatments 1 and 3). Nitrogen alone increased the barley

Table 2. Average Yields of Various Crops in Two Irrigated Rotations at Redfield as Influenced by 10 Fertilizer Treatments. Corn and Alfalfa Yields Are Averages of 4 Years, 3 Replications, and First and Second Year Crops in Each Rotation. Barley Yields Are Averages of 4 Years and 3 Replications in Each Rotation*

	Fertilizer Treatment Numbers									
	1	2	3	4	5	6	7	8	9	10
Rotation A										
Barley	42	48	46	52	49	55	53	52	55	56
Alfalfa	4.53	4.47	5.23	4.97	5.09	4.68	4.70	4.72	4.61	4.63
Corn	96	97	99	102	102	97	103	100	103	99
Rotation B										
Barley	20	47	22	49	31	43	53	50	51	50
Corn	59	97	59	88	91	88	100	95	96	96

*Barley and corn yields are in bushels per acre. Alfalfa yields are in tons per acre.

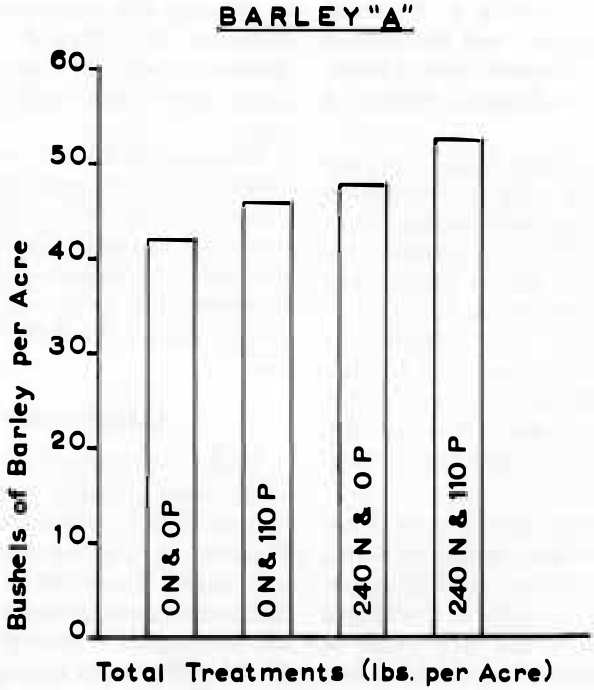

Figure 1. Effect of various total fertilizer treatments on the yields of irrigated barley in Rotation A.

yield by about 6 bushels (difference between treatments 1 and 2). However, when nitrogen and phosphorus were combined, as in treatment 7, the yield was increased 11 bushels above treatment 1. From these data it appears that some nitrogen and phosphorus fertilizer is required for maximum yields.

Barley yields in Rotation B (barley-corn-corn) are found in table 2, while the relationships between total treatments and barley yields are shown graphically in figures 2 and 3. Figure 2 shows very little increase for phosphorus (comparison of treatments 1 and 3), but a 27 bushel increase (135%) for nitrogen alone (difference between treatments 1 and 2). The combination of nitrogen and phosphorus (treatment 7) returned 33 bushels of barley above the treatment 1 yield, a 165% increase. Therefore, phosphorus in combination with nitrogen will produce significant yield increases, but little yield increase is realized for phosphorus alone.

Some barley yields in Rotation B were plotted against various total nitrogen treatments in figure 3 while holding the phosphorus at a constant rate of 66 pounds per acre. The point on the graph which rep-

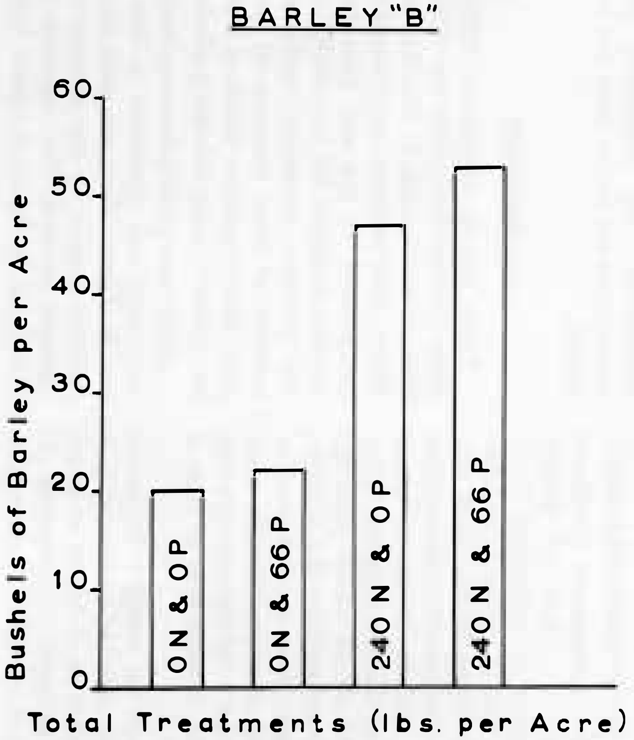

Figure 2. Effect of various total fertilizer treatments on the yields of irrigated barley in Rotation B.

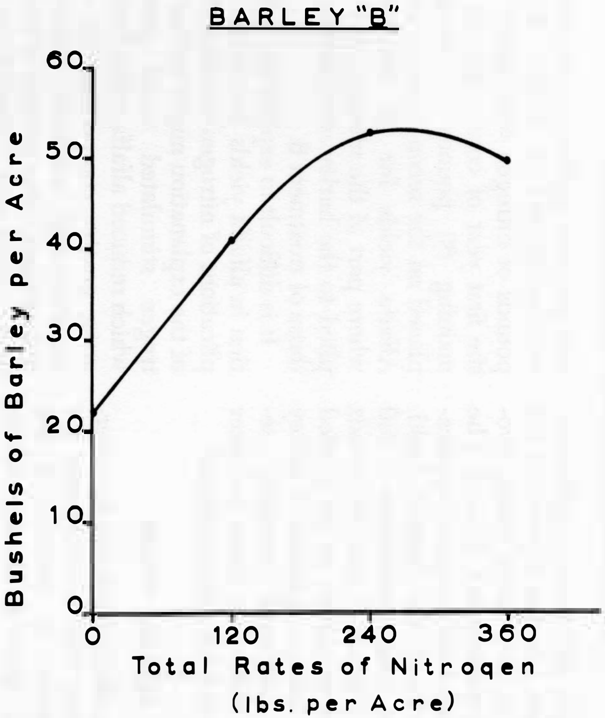

Figure 3. Effect of various total rates of nitrogen on the yields of irrigated barley in Rotation B. Phosphorus was included in all treatments at the rate of 66 pounds per acre.

resents the 120 pound application of nitrogen (for the 3 years) is the average of the barley yields produced by treatments 4, 5, and 6. The 240 pound total nitrogen application produced the highest yield. Therefore, total applications of 240 pounds of nitrogen and 66 pounds of phosphorus seem to be needed for near maximum yields of barley in this particular cropping sequence. However, these fertilizer rates are not the most profitable.

ALFALFA YIELDS

Alfalfa yields produced by several fertilizer treatments (totals for the rotation) in Rotation A are plotted in figure 4. These yields illustrate two phenomena resulting from fertilizer applications. First, the addition of phosphorus fertilizer increased alfalfa yield .70 ton (comparison of treatments 1 and 3).

Secondly, nitrogenous fertilizers decreased the yield of alfalfa. A comparison of treatments 1 and 2 reveals that the addition of nitrogen alone depressed the yields only slightly where fertilizer phosphorus was not added. However, where phosphorus had been applied as fertilizer, the alfalfa yields were appreciably reduced by the addition of nitrogen. This can be seen by comparing treatment 3 with treatments 5 and 6. All the nitrogen was applied on the first year of corn in treatment 5.

Although the nitrogen depressed the alfalfa yield in treatment 5, it did not depress it nearly as much as the nitrogen applications in treatment 6, in which 20 pounds of nitrogen was applied to the barley interseeded with alfalfa. Forty pounds of nitrogen was applied on the first year of corn, with the remaining 60 pounds of nitrogen placed on the second year of corn. Alfalfa yields for all treatments where part of the nitrogen was applied to the barley were similar to those of treatment 6.

It is difficult to explain the reduction in alfalfa yields due to the applications of nitrogen fertilizer. Part of the explanation might be that nitrogen stimulated weed growth which reduced alfalfa yields by creating greater competition for soil moisture and nutrients. Nitrogen did increase foliar growth of barley to the extent that it shaded out the alfalfa seedlings, thereby reducing the stand of alfalfa. Reseeding alfalfa in plots having high nitrogen applications was frequently required after the barley crop was removed.

CORN YIELDS

There are no significant differences among corn yields for Rotation A listed in table 2. This fact indicates that nitrogen and phosphorus present in the soil plus the amount supplied by the alfalfa in the rotation furnished sufficient amounts of these elements to produce near maximum yields of corn for at least 2 years following alfalfa.

Many corn yield differences were very large and significant in Rotation B. These differences were conditioned largely by the amount of nitrogen applied. This situation is illustrated in figure 5 where corn

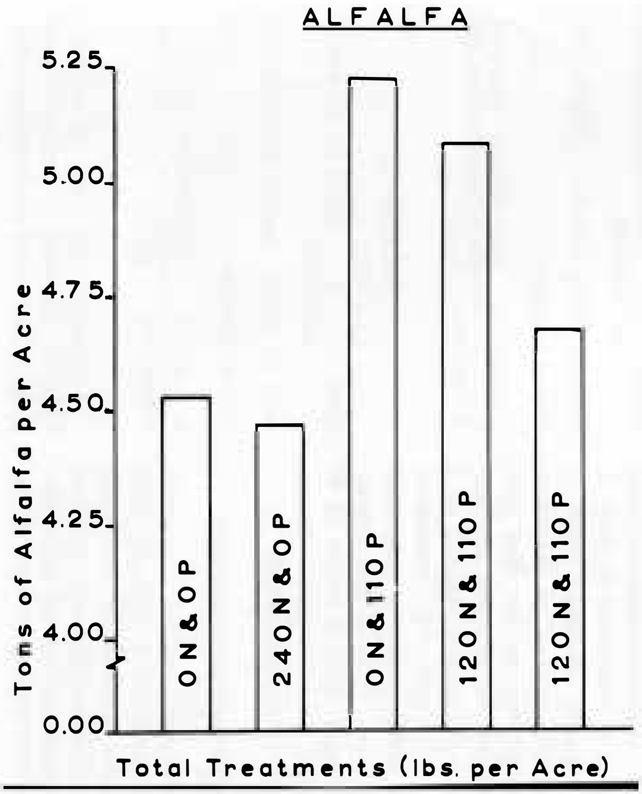

Figure 4. Effect of various total fertilizer treatments on the yields of irrigated alfalfa in Rotation A.

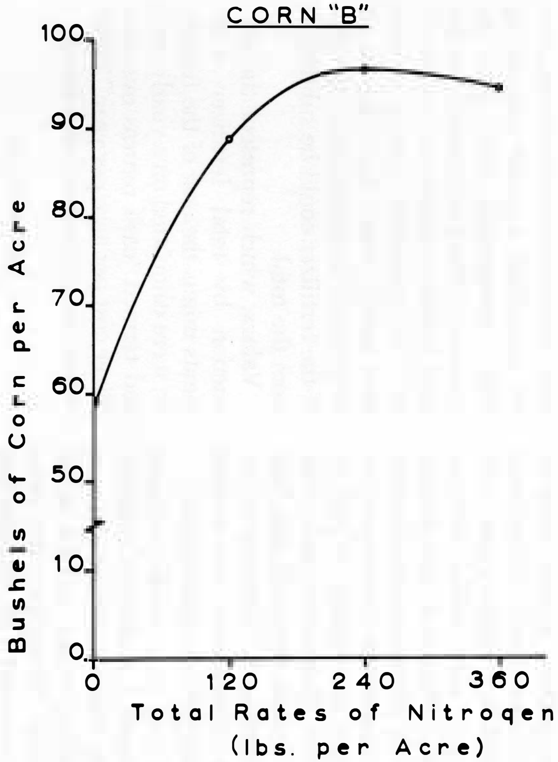

Figure 5. Effect of various total rates of nitrogen on the yields of irrigated corn in Rotation B. Phosphorus was included in all treatments at the rate of 66 pounds per acre.

yields are plotted against some of the total treatments. Phosphorus was applied at a constant rate of 66 pounds per acre while nitrogen rates varied from 0 to 360 pounds per acre in these total treatments. The 240 pound rate of nitrogen produced maximum yields of corn in this rotation. This corresponds closely to the results obtained with barley in Rotation B. Little or no response to phosphorus was evident in the corn yields in this rotation.

Barley and corn yields produced by treatments 4, 5, and 6 in Rotation B indicate that insufficient nitrogen was supplied to the soil for maximum yields throughout the rotation. In treatment 4 all nitrogen was applied on the second year of corn. Enough nitrogen was carried over to produce near maximum yields of barley, but not enough nitrogen was left to produce maximum yields of corn, as is evidenced in table 2.

The opposite situation exists in treatment 5 where all of the nitrogen was placed on the first year corn. Where the nitrogen application was split up and applied all 3 years (treatment 6), maximum yields of either barley or corn were not obtained. Thus in this experiment nitrogen rates in excess of 40 pounds per acre per year were essential for maximum yields.

ECONOMIC EVALUATION

An economic analysis was made of this experiment to evaluate fully the various methods of fertilizing the two rotations. It was impossible to determine the amount of fertilizer carryover from one year to the next, and to add yields of corn, barley, and alfalfa together and end up with a meaningful value. Some expression of the production from the total fertilizer treatment was needed. The monetary system seemed best suited, since the value of all crops could be added and the value of the fertilizer could be subtracted from the total.

Values, which represent the production by total fertilizer treatments minus the cost of the fertilizer, were calculated on a yearly basis and termed "cash returns over fertilizer cost per acre per year." These values were calculated as follows:

ROTATION A

Yields of 1st yr Corn + 2nd yr Corn (bu/A) x \$1/bu=A

Yields of 1st yr Alfalfa + 2nd yr Alfalfa (tons/A) x \$15/ton=B

Yield of Barley (bu/A) x \$.85/bu=C

Cost of Fertilizer ....=D

$$\frac{A+B+C-D}{5 \text{ crop years}} = \text{Cash Returns Over Fertilizer Cost Per Acre Per Year}$$

ROTATION B

Yields of 1st yr Corn + 2nd yr Corn (bu/A) x \$1/bu=A

Yield of Barley (bu/A) x \$.85/bu=B

Cost of Fertilizer ....=C

$$\frac{A+B-C}{3 \text{ crop years}} = \text{Cash Returns Over Fertilizer Cost Per Acre Per Year}$$

Fertilizer cost was calculated from the amount of fertilizer used for the total fertilizer treatment. Ni-

Table 3. Cash Returns Over Fertilizer Cost Per Acre Per Year as Influenced by 10 Fertilizer Treatments in Two Irrigated Rotations at Redfield

	Fertilizer Treatment Numbers									
	1	2	3	4	5	6	7	8	9	10
Rotation A	$72.75	$67.72	$74.11	$71.71	$72.06	$68.54	$67.43	$63.44	$69.62	$68.29
Rotation B	$45.21	$67.92	$40.79	$62.51	$60.08	$61.27	$67.03	$57.73	$66.14	$65.96

trogen was valued at 12.6c a pound of N; phosphorus at 21.2c a pound of P. All other operating costs and land costs were omitted since they would not change from treatment to treatment within a given rotation. However, to determine net income per acre, these additional costs would have to be considered.

Cash returns over fertilizer cost per acre per year for the various treatments in Rotation A are plotted in figure 6 and listed in table 3. The highest cash return was produced by treatment 3 where phosphorus was the only element added. Treatment 3 produced a cash return of approximately $74, whereas treatment 1, which included no fertilizer, returned almost $73 per acre per year.

All treatments containing nitrogen reduced the cash return to less than that of treatment 1. This reduction is clearly illustrated in figure 7. The graph shows that as the rate of nitrogen is increased while holding the phosphorus constant, the cash return is decreased in an almost straight line relationship.

It might be possible to use less phosphorus than was used in treatment 3 and still maintain the same yields while increasing the cash return. Treatments 7 and 9 in figure 6 and table 3 appear to support this hypothesis. Treatment 9 supplied only 55 pounds of phosphorus per acre to the soil while treatment 7 supplied 110 pounds. Treatment 9 had a higher return per acre than treatment 7. Both treatments included a total of 240 pounds of nitrogen per acre.

In conclusion, a study of the results of Rotation A reveal that the total fertilizer application that produced the highest cash return was 110 pounds of phosphorus per acre applied to the soil prior to planting the barley. It may even be possible to reduce this amount of phosphorus to 55 pounds of P per acre and increase the cash return.

Cash returns over fertilizer cost per acre per year for the total treatments included in Rotation B are graphed in figures 8 and 9 and listed in table 3. Inspection of these two graphs leads to two conclusions. First, the use of nitrogen greatly increased the monetary return. This is best demonstrated in figure 8, where the cash returns are plotted against varying rates of nitrogen at a constant level of phosphorus. The graph shows that the maximum cash return is realized at about 240 pounds of nitrogen per acre for the 3-year cycle. This corresponds closely with the yield responses, since near maximum yields of bar-

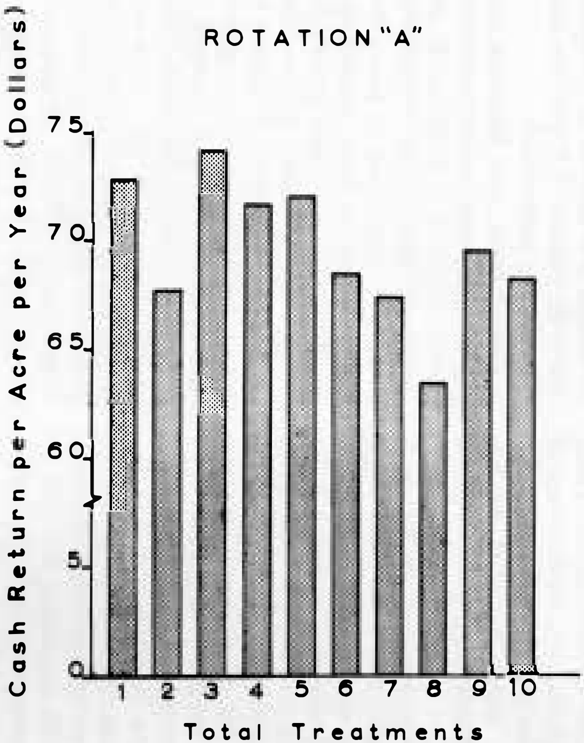

Figure 6. Cash returns over fertilizer cost per acre per year as influenced by the various total treatments in Rotation A.

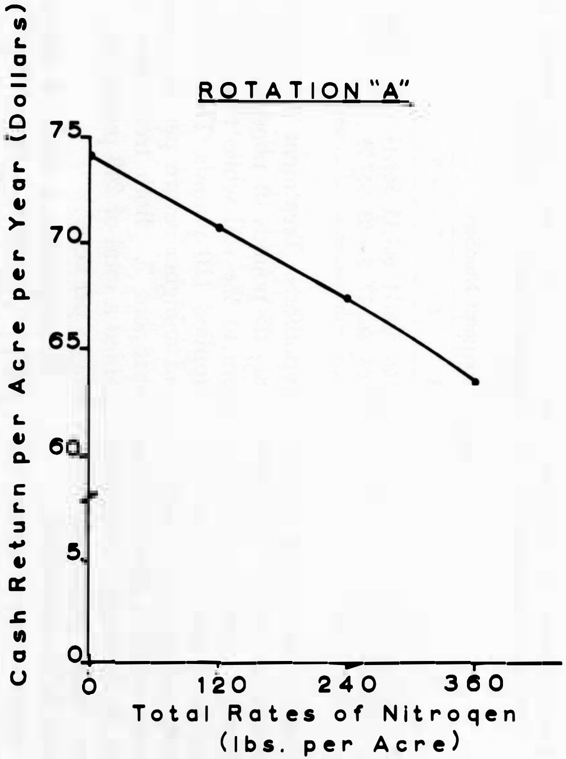

Figure 7. Cash returns over fertilizer cost per acre per year as influenced by various total rates of nitrogen in Rotation A. Phosphorus was included in all treatments at the rate of 110 pounds per acre.

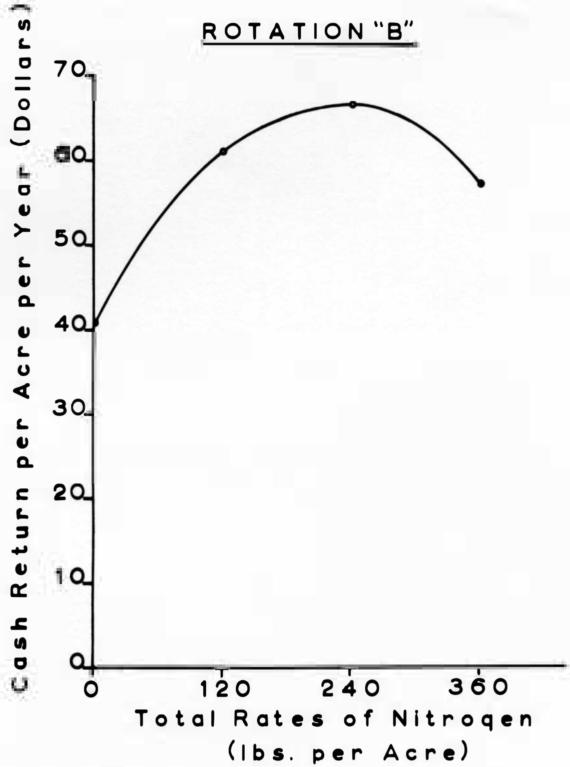

Figure 8. Cash returns over fertilizer cost per acre per year as influenced by various total rates of nitrogen in Rotation B. Phosphorus was included in all treatments at the rate of 66 pounds per acre.

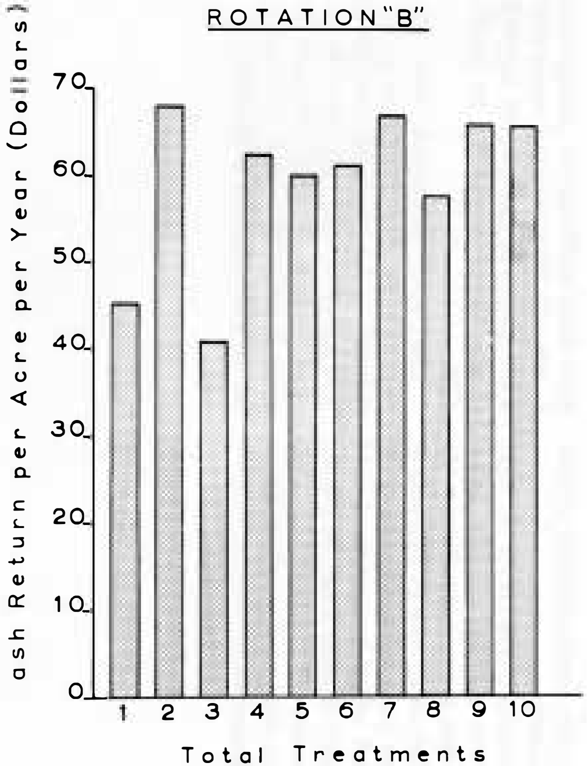

Figure 9. Cash returns over fertilizer cost per acre per year as influenced by the various total treatments in Rotation B.

ley and corn were obtained at this rate of nitrogen.

The second conclusion is that phosphorus applied at the rates used in this experiment did not increase the cash return. In fact, it may have reduced it slightly, as is evidenced when treatments 1 and 3 in figure 9 or table 3 are compared. A comparison of treatments 2, 7, 9, and 10 in the same graph or table demonstrates no increase in cash return from additions of phosphorus to the soil. This does not mean that a lower rate of phosphorus applied to the barley would not be profitable.

The total treatment that appeared to be most profitable in Rotation B is the use of 240 pounds of N applied to the soil over the 3-year period. A small amount of phosphorus might prove to be profitable when applied to the barley.