The Effect of Alfalfa on the Yields of Non-Leguminous Crops in a Rotation[1]

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Alfalfa is highly valued as a feed crop and has a good reputation as a "soil builder," but not all people agree that there is a net gain in soil fertility from alfalfa in a crop rotation if it is harvested for hay and no manure returned to the soil. Some have advanced the theory that the observed benefits from alfalfa are due to its solvent effect on mineral nutrients and a consequent increase in their availability to plants. Others attribute the benefits to a net contribution to the soil nitrogen supply.

Recently, pronounced benefits from alfalfa in a rotation have been obtained in an experiment now in progress on the Colorado A 8c M College Agronomy Farm. Information has also been obtained which indicates what the probable major reasons for the benefits are and what influence alfalfa in a rotation may have on need for fertilizers.

Table 1.—The Effect of Rotations on the Yield of Beets Under Different Fertilizer Treatments (Tons Per Acre)

	A. Beets after Corn							
	1950					1951		
	No Fert.	P	N	NP	None	P	N	NP
8-Year	12.83	16.68	14.00	17.42	13.49	15.54	12.32	15.09
5-Year	7.69	10.22	12.21	14.93	8.24	8.97	12.77	18.21
Difference	5.14	6.46	1.79	2.49	5.25	6.57	—0.45	—3.12
	B. Beets after Wheat							
8-Year	11.33	14.37	12.52	17.05	8.87	12.68	10.21	18.95
5-Year	7.08	10.38	10.46	17.85	8.82	8.77	10.91	17.52
Difference	4.25	3.99	2.06	—0.80	— .05	3.91	—0.70	1.43

Test Started in 1935

The experiment, which was started in 1935, consists of a comparative study of two rotation systems differing initially from each other only in the occurrence of three crop years of alfalfa in one rotation and not in the other. Later, when phosphate was applied, the average rate was less in the alfalfa

Table 2.—The Effect of Rotations on Yield of Sugar Under Different Fertilizer Treatments (Lbs. Per Acre).

	A. Beets after Corn							
	1950					1951		
	No Fert.	P	N	NP	None	P	N	NP
8-Year	4,703	6,025	5,291	6,144	4,737	5,168	3,572	4,487
5-Year	2,886	3,830	4,566	5,456	2,727	3,078	4,058	6,283
Difference	1,817	2,195	725	688	2,010	2,090	—486	—1,796
	B. Beets after Wheat							
8-Year	4,273	5,311	4,688	6,318	3,016	4,420	3,094	5,854
5-Year	2,652	4,064	3,976	6,970	3,128	3,044	3,555	5,826
Difference	1,585	1,247	712	—652	—112	1,376	—460	28

[1]Contributed from the Agronomy Section Colorado Agricultural Experiment Station, Fort Collins, Colo. Published with the approval of the Director of the Colorado Agricultural Experiment Station as Scientific Series Paper No. 385.

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rotation since applications were made to only 2 plots out of 8 each year instead of to 2 plots out of 5 as in the other rotation. The sequence of crops, exclusive of alfalfa, is corn, sugar beets, wheat, sugar beets and barley

Table 3.—The Effect of Rotations on the Yield of Beet Tops Under Different Fertilizer Treatments (Tons Per Acre).

	A. Beets after Corn							
	1950				1951			
	No Fert.	P	N	NP	None	P	N	NP
8-Year	17.64	18.79	18.62	22.77	13.39	14.34	20.01	18.21
5-Year	8.08	8.58	13.07	13.40	6.53	6.29	18.64	14.69
Difference	9.56	10.21	5.55	9.37	6.86	8.05	1.37	3.52
	B. Beets after Wheat							
8-Year	10.87	10.45	13.58	12.50	9.94	8.40	17.29	17.14
5-Year	7.02	5.55	12.09	10.78	5.95	6.05	14.93	13.65
Difference	3.85	4.90	1.49	1.72	3.99	2.30	2.36	3.49

in both rotations. A complete cycle of the rotation without alfalfa is, therefore, five years and, in the rotation which includes alfalfa, eight years. In the eight-year rotation alfalfa is planted with the barley but no alfalfa is harvested the first year of growth.

The alfalfa stubble and third crop of hay, varying from 1/2 to 1 ton per acre, is plowed under in late fall of the third crop year. The rotations are in duplicate and all crops on each rotation are produced each year.

Table 4.—The Effect of Rotations on the Yield of Cereals Under Different Fertilizer Treatments (Bu. Per Acre).

	Corn							
	1950				1951			
	No Fert.	P	N	NP	None	P	N	NP
8-Year	74.1	64.0	65.7	63.5	39.9	50.2	42.4	45.4
5-Year	42.4	50.2	46.9	67.7	28.1	35.0	35.8	43.6
Difference	31.7	13.8	18.8	—4.3	11.8	15.2	6.6	1.8
	Wheat							
8-Year	30.6	38.3	24.4	41.2	38.9	41.0	40.8	42.3
5-Year	23.5	24.2	27.0	30.1	26.7	28.1	35.0	39.4
Difference	7.1	13.1	—2.6	11.1	12.2	12.9	5.8	2.9
	Barley							
8-Year	51.2	62.1	74.9	68.3	44.8	47.6	65.6	74.6
5-Year	37.2	36.1	44.3	70.6	31.7	30.8	51.9	69.9
Difference	14.0	26.0	30.6	—2.3	13.1	16.8	13.7	4.7

No manure, except the small third cutting of alfalfa added as green manure before each corn crop in the 8-year rotation, has been added to either rotation. No commercial fertilizers were added during the first 7 years of the experiment. Since that time, the study has been conducted as a split plot experiment and phosphate has been added to one-half of each sugar beet plot annually at the rate of 54 pounds of P_2O_5 per acre until 1949 and 86 pounds per acre since that time. In 1950, the experiment was divided into quarters and nitrogen was added at the rate of 66 pounds per acre to two of the four subdivisions of all plots in the experiment. The same two subdivisions were fertilized again in 1951 at the rate of 100

pounds of nitrogen per acre. One quarter has received no fertilizer, one phosphorus only, one nitrogen only and the fourth both nitrogen and phosphorus.

Alfalfa and Fertilizer Contributions to Yields[3]

Some of the major results of the experiments are summarized in the tables included in this paper. Tables 1 to 4 show yields per acre for 1950 and 1951 of all crops in both rotations under the different fertilizer treatments. Table 5 shows the increases in yields of all crops which can be attributed to effects of alfalfa. The increases were calculated by subtracting the 5-year rotation yields from the 8-year rotation yields. Approximate cash values of the increases are also shown in Table 5. Table 6A and 6B show the comparative increases due to fertilizers on each rotation and the cash values of the increases. The increases were calculated by subtracting the yields of the unfertilized plots from comparable yields of the fertilized plots.

Table 5.—Increased Yields and Cash Returns Due to Alfalfa in a Crop Rotation. (Per acre value for each crop).

	Increased Yields (tons and bu.)				Increased Cash Returns[1]			
	No Fert.	P	N	NP	None	P	N	NP
Beets (1st)	5.20	6.52	0.67	—0.32	$62.40	$78.24	$ 8.04	$—3.84
Beets (2nd)	2.15	3.95	0.68	0.32	25.80	47.40	8.16	3.84
Corn	21.75	14.50	12.70	—1.25	38.28	25.52	22.35	—2.20
Wheat	9.65	13.00	1.60	7.00	20.26	27.30	3.36	14.70
Barley	13.55	21.40	22.15	1.20	17.21	27.18	28.13	1.52
			Total (5 acres)		163.95	205.64	70.04	14.02
			Average increase per acre		32.79	41.13	14.01	2.80
			L S D. = 30.89 at 1 pct. point					

[1] Values based upon $12.00 per ton of beets, $1.76 per bu. corn, $2-10 per bu. wheat, $1.27 per bu. barley.

Table 6A.—Increased Yields and Cash Return Due to Fertilizers in 8-Year Rotation—Two Year Average.

Increased Yields			Increased Cash Returns		
P	N	NP	P	N	NP
		Beets after Corn (Tons)			
3.95	0.00	3.20	$47.40	$ 0.00	$38.40
		Beets after Wheat (Tons)			
3.43	1.27	7.90	41.16	15.24	94.80
		Corn (Bu.)			
0.10	—2.95	—2.55	0.18	—5.19	—4.49
		Wheat (Bu.)			
4.90	—2.15	7.25	10.29	—4.52	15.23
		Barley (Bu.)			
6.85	22.25	23.45	8.70	28.26	29.78
		Total (5 acres)	107.73	33.79	173.72
		Fertilizer Cost	14.00	57.20	71.20
	Total Minus	Fertilizer Cost	93.73	—23.41	102.52

The comparative yields for the two rotations with no fertilizer are shown in the lefthand columns of the 1950 and 1951 figures of Tables 1

[3] For the sake of simplicity, the statistical analyses are omitted. The major effects presented are highly significant.

to 4, headed "No Fert." These yields are consistently higher in the 8-year than in the 5-year rotation. From this column alone, *no* specific cause can be assigned to the differences other than that they are due to alfalfa. However, when it is further observed in the other columns that the 8-year rotation gave the greatest response to phosphate alone, the 5-year rotation to nitrogen alone and to nitrogen plus phosphorus, there is good evidence in support of the following conclusions:

(1) That the unfertilized plots in both rotations were markedly deficient in available phosphorus; (2) that the 5-year rotation was much more deficient in nitrogen than the 8-year rotation, and (3) that nitrogen contributed by the alfalfa was the principal cause of the greater yields from the 8-year rotation. The visual appearance of the crop and crop analysis have supported these conclusions.

Table 6B.—Increased Yields and Cash Returns Due to Fertilizers in 5-Year Rotation—Two Year Average.

Increased Yields			Increased Cash Returns		
P	**N**	**NP**	**P**	**N**	**NP**
		Beets after Corn (tons)			
1.63	4.53	8.63	$19.56	$54.36	$103.56
		Beets after Wheat (tons)			
1.63	2.47	9.74	19.56	29.64	**116.88**
		Corn (bu.)			
5.60	—0.35	7.70	9.86	—0.62	13.55
		Wheat (bu.)			
1.05	5.90	9.40	2.21	12.39	19.74
		Barley (bu.)			
—0.01	13.65	35.80	—0.01	17.34	45.47
		Total (5 acres)	51.18	113.11	299.20
		Fertilizer cost	14.00	57.20	71.20
		Total Minus Fertilizer Cost	37.18	56.91	228.00

Table 5 shows the economic importance of alfalfa in the rotation. In the lefthand half of the table the yield differences which can be attributed to alfalfa are given and the right half portion shows estimated cash values of these differences under the various fertility levels. It is evident from this table that at high fertility levels resulting from nitrogen and phosphorus fertilization the benefits from alfalfa were much less than where no fertilizer was applied or where phosphorus only was applied.

The greatest difference between rotations occurred where phosphorus only was applied and the least difference occurred where nitrogen and phosphorus were used in combination. The difference between the two rotations was small and statistically insignificant when both rotations received nitrogen and phosphorus. In all other cases the 8-year rotation gave significantly greater cash returns.

The data in Tables 6A and 6B summarize the increased yields obtained at different nitrogen and phosphorus levels and the cash values of the increases. There was a net loss from the use of nitrogen alone on the 8-year rotation when the cost of fertilizer was considered. The profit from phosphorus alone on the 8-year rotation was significantly greater than on the 5-year rotation. Nitrogen alone or the combination of nitrogen and phosphorus was profitable *in* the 5-year rotation.

The data, as a whole, indicate that (1) on land which is not well-fertilized with nitrogen carrying materials, alfalfa will contribute materially to crops which follow it in a rotation; (2) alfalfa in a rotation does not minimize the necessity for mineral fertilizers; (3) where large quantities of nitrogen fertilizers are used the contribution of alfalfa is less important.