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Legume Rotations— Crop Yields and Nitrogen Fixation[1]

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It is well known that legumes have beneficial effects on succeeding crops. The benefit has been attributed to nitrogen fixation and improved soil physical conditions. Legumes such as alfalfa and red clover also provide high quality forage rich in protein, so little if any protein supplement is needed in livestock rations. Nitrogenous fertilizers at a relatively cheap price gave farmers an alternative source of nitrogen for grain production.

This report compares legume rotations with continuous grain production with and without nitrogen fertilization at the Cornbelt Experiment Field in northeastern Kansas to determine legume effects on cereals grown in rotation.

Four cropping systems with three levels of nitrogen were established in 1958. The four cropping sequences were: continuous corn (C); corn, corn, oats (CCO); corn, corn, oats, red clover(CCOR); and corn, corn, oats, alfalfa, al-

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falfa (CCOAA). Nitrogen was applied to the corn at 0, 80, or 160 pounds per acre with a constant 40 pounds per acre of P_2O_5. Oats received nitrogen at 0, 40, or 80 pounds per acre in the CCO sequence but none in the CCOR or CCOAA rotations. Phosphorus was applied at 35 pounds of P_2O_5 per acre to the oats and at 25 pounds per acre to the alfalfa and red clover. The legumes were established by overseeding them in oats in the rotation. The study continued through 1968. Yield data are from 1962 through 1968.

Results and Discussion

Response to nitrogen was marked in continuous corn and the CCO sequence (Table 1).

Table 1: Crop yields as influenced by crop sequence and added nitrogen fertilizer, 7-year averages, 1962 through 1968.

Crop sequence and nitrogen rate[1] Pounds per acre	Yields—bu/acre and tons/acre[2]					
	1st yr corn	2nd yr corn	oats	red[3] clover	1st yr[3] alfalfa	2nd yr alfalfa
Continuous Corn (C)						
0	34					
80	79					
160	80					
Corn, Corn, Oats (CCO)						
0	39	40	24			
80	79	79	39			
160	84	82	37			
Corn, Corn, Oats, Red Clover (CCOR)						
0	70	69	33	1.98		
80	80	87	41	2.15		
160	82	87	43	1.99		
Corn, Corn, Oats, Alfalfa, Alfalfa, (CCOAA)						
0	64	85	44		2.48	3.29
80	65	89	47		2.44	3.37
160	66	86	43		2.30	3.37

1. Nitrogen rates were 0, 40, and 80 pounds per acre for oats and 0, 80, and 160 for corn. Red clover and alfalfa received no nitrogen fertilizer.
2. Yields of corn and oats corrected to 15½% moisture. Hay yields are air dry weights.
3. No hay yields were obtained for red clover and first year alfalfa in 1965 as stands were not established in 1964. They were reseeded in the fall of 1964 and again in April, 1965.

Most response was to 80 pounds per acre of nitrogen as 160 pounds per acre increased yields little more. In the CCOR sequence the first 80 pounds of nitrogen increased yields of first and second year corn but much less than in the continuous corn or CCO rotations. Low corn yields the first year after alfalfa are believed to have resulted from soil moisture depletion by the alfalfa and moisture stress on the corn. Second year corn yields in alfalfa or red clover rotations with 80 or 160 pounds per acre of nitrogen exceeded yields from other cropping sequences.

The data suggest that corn after red clover requires less than 80 pounds of nitrogen for optimum yield, and corn following two years of alfalfa requires no added nitrogen. The reduced yield of corn the first year after alfalfa makes it impossible to evaluate the nitrogen replacement value of alfalfa. Corn yields after red clover compared with continuous-corn yields suggest that red clover was equal to about 70 pounds of nitrogen per acre.

Residual nitrogen from preceding crops in the rotation had little influence on yields of alfalfa and red clover. First year alfalfa yields exceeded red clover yields but were lower than second year alfalfa yields.

Income from the various cropping systems is of major importance. Average yearly gross returns per acre are shown in Table 2. With yields around 90 bushels per acre, continuous corn and 80 pounds per acre of nitrogen should give highest net returns.

Low yields of oats and low prices for oats suggest excluding them as a cash crop from commercial crop production in northeastern Kansas.

Eighty pounds per acre of nitrogen increased gross income $26.60 from continuous corn compared with corn in the CCOAA rotation with no nitrogen. Such an increase would permit paying up to 33 cents per pound for 80 pounds of nitrogen on continuous corn and break even assuming no adjustment for differences in production costs. However, the increased yield would involve higher handling costs so the 33 cents is somewhat high. Shifts in crop prices would change gross income from that shown in Table 2. Shifts in fertilizer prices and other production costs would change net income, which is the important figure to farmers. One must also recognize that individual farming systems often include livestock that need forages.

Table 2: Yearly gross income for indicated cropping sequences, based on prices for 1962 through 1968.[1]

Cropping sequence and nitrogen rate Pounds per acre	Average yearly gross income dollars per acre
Continuous Corn (C)	
0	$38.59
80	87.30
160	88.01
Corn, Corn, Oats, (CCO)	
0	35.69
80	68.09
160	70.70
Corn, Corn, Oats, Red Clover (CCOR)	
0	52.90
80	62.49
160	62.61
Corn, Corn, Oats, Alfalfa, Alfalfa (CCOAA)	
0	61.24
80	62.91
160	61.54

1. Corn per bushel: $ .89 in 1962, $1.14 in 1963, $1.20 in 1964, 1965, and 1966, $1.10 in 1967, and $1.07 in 1968.
Oats per bushel: $ .78 in 1962, $ .75 in 1963 and 1965 through 1968, and $ .72 in 1964.
Red clover per ton: $14.20 in 1962, $21.00 in 1963, $18.00 in 1964 and 1965, $20.00 in 1966 and 1967, and $12.00 in 1968.
Alfalfa per ton: $16.00 in 1962, $15.62 in 1963, $20.00 in 1964 and 1966, $18.00 in 1965 and 1968, and $25.00 in 1967.

When the experiment ended, soil samples were taken to 10 feet deep from two replications of continuous corn and from corn plots planted in 1968 in the CCOAA sequences and analyzed for inorganic nitrogen (Table 3). The greater accumulation of inorganic nitrogen in the 160-pound nitrogen fertilizer plots over the 80-pound nitrogen plots shows the 160 pound rate to be excessive for yields obtained. Less inorganic nitrogen in the CCOAA rotation soils probably resulted from no nitrogen being applied to the alfalfa in the rotation and to alfalfa removing nitrogen.

Table 3: Inorganic nitrogen in soil profile after corn in two cropping systems.[1]

Crop sequence and nitrogen rate	Lbs/acre of accumulated inorganic nitrogen[2]			
Pounds per acre	0-12"	0-24"	0-60"	0-120"
Continuous Corn (C)				
0	39.9	63.0	114.9	310.2
80	47.3	73.1	168.2	417.4
160	47.4	75.6	217.7	663.4
1st year Corn after Alfalfa				
0	27.9	52.1	117.2	299.0
80	34.9	53.6	145.3	339.2
160	32.9	49.4	172.8	414.1
2nd year Corn after Alfalfa				
0	24.1	36.0	80.0	304.6
80	34.4	44.0	93.0	366.8
160	32.4	43.8	119.4	386.5

1. Sampled spring, 1969.
2. Average of two replications.