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Fertilization of Small Grain Crops in Missouri

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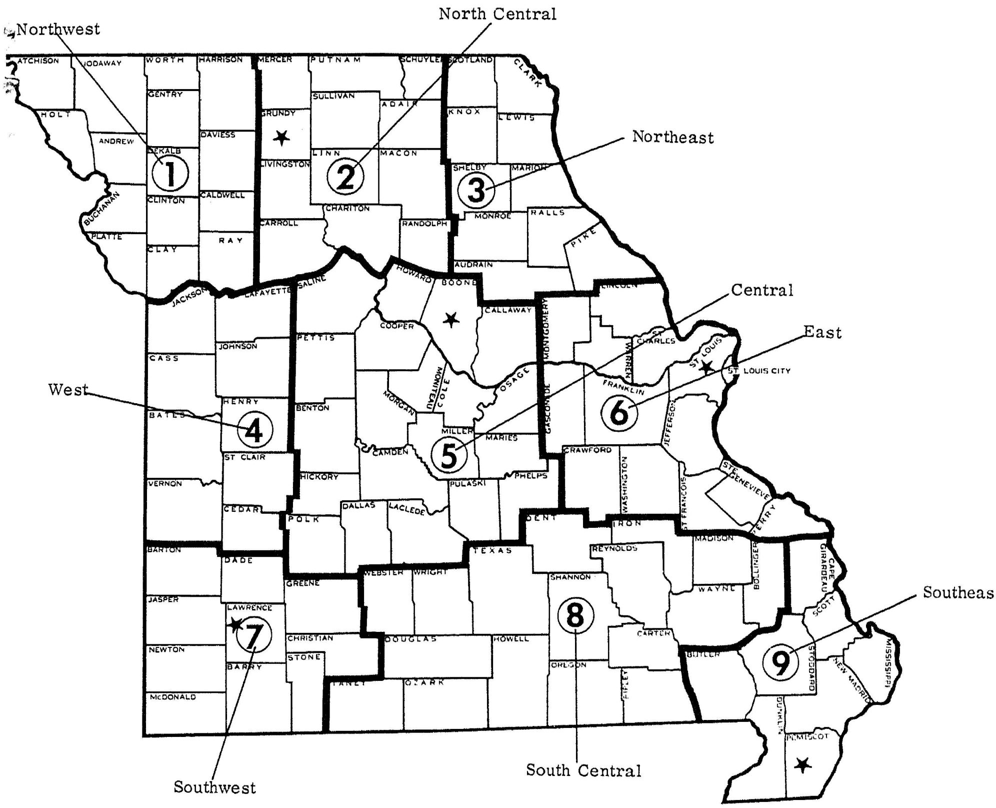

Figure 1---Regions of Missouri delineated by the Missouri Crop and Livestock Reporting Service, Missouri Farm Facts (1). Stars locate Missouri Agricultural Experiment Station Centers.

Introduction

The University of Missouri - Columbia Agricultural Experiment Station has conducted much research on soil fertility requirements of small grain in various soil types and regions over the state. This bulletin summarizes results of this research at the Southwest Center, Mt. Vernon; Delta Center, Portageville; Weldon Spring Center; Bradford Farm, Columbia; and North Missouri Center, Spickard.

TABLE 1--ACREAGE, YIELD AND VALUE OF WHEAT, OATS AND BARLEY GROWN IN MISSOURI 1956 - 1966

	Wheat				Oats*				Barley			
	Acres	Yield		Value	Acres	Yield		Value	Acres	Yield		Value
Year	1,000 Acres	1,000 Bushels	Bus/ Acre	1,000 dollars	1,000 Acres	1,000 Bushels	Bus/ Acre	1,000 dollars	1,000 Acres	1,000 Bushels	Bus/ Acre	1,000 dollars
1956	1,660	50,630	30.5	96,703	1,303	40,393	31.0	27,467	438	11,826	27.0	10,880
1957	1,643	37,789	23.0	72,555	1,055	33,760	32.0	21,944	359	7,898	22.0	7,029
1958	1,446	40,488	28.0	68,830	696	22,272	32.0	13,809	231	7,566	26.0	6,280
1959	1,518	37,950	25.0	65,274	675	17,888	26.5	11,985	210	5,670	27.0	4,766
1960	1,321	37,648	28.5	64,755	499	17,465	35.0	11,352	136	4,488	33.0	3,590
1961	1,374	41,907	30.5	73,756	439	15,365	35.0	10,295	140	4,900	35.0	4,116
1962	976	26,352	27.0	52,177	316	9,164	29.0	6,415	101	2,626	26.0	2,390
1963	1,191	39,303	33.0	71,531	348	14,616	42.0	10,524	71	2,130	30.0	1,960
1964	1,429	46,442	32.5	65,019	310	11,780	38.0	8,010	43	1,462	34.0	1,301
1965	1,186	32,615	27.5	43,378	189	6,615	35.0	4,804	29	928	32.0	683
1966	1,210	41,140	34.0		246	9,840	40.0		21	714	34.0	
1967**	1,718	54,976	32.0		226	9,040	40.0		19	684	36.0	

* Both spring and winter oats.
**Indicated acreages and yields.

Small grains have played an important part in the agricultural economy of Missouri. Oats have served a double purpose as a nurse crop for forage seedlings and as feed for farm animals. Barley has been grown principally in dairy areas where corn was a questionable crop because of drouth or erosion hazards. Wheat has always been an important source of farm income and with the demands for food grains by an increasing national and world population it could increase in importance. Wheat acreages fluctuated during the ten year period, 1956-1966, and reached a record high in 1967. (Table 1) (1) Oat and barley acreages steadily declined during the same period.

Wheat is grown in all sections of Missouri, the smallest acreage being in the south central portion (Figure 1 and Table 2). (1) A large acreage was planted to wheat in southeast Missouri in 1966 and 1967 due to unfavorable weather conditions for cotton. Oats tend to be grown more by regions and vary from county to county within a region, depending on their demand as feed for dairy cattle. Barley is still more limited to the dairy areas of southwest and extreme eastern portions of the state.

Smith, *et al.* (2) have pointed out that profitable yields of small grains in Missouri depend on the use of commercial fertilizers.

The University of Missouri - Columbia Agricultural Experiment Station, between 1955 and 1960, increased the opportunities for evaluating many of the newer plant nutrient carriers on Missouri soils (Figure 1).

TABLE 2--ACREAGES AND PRODUCTION OF WHEAT AND OATS BY REGIONS - 1966

Region	Wheat			Oats		
	Acres	Bu./A	Total	Acres	Bu./A	Total
North West	107,000	33.1	3,547,000	35,000	40.5	1,417,000
North Central	114,000	34.2	3,894,000	44,000	44.3	1,950,000
North East	129,000	33.1	4,276,000	36,000	44.8	1,613,000
West	143,000	29.1	4,166,000	32,000	37.4	1,198,000
Central	164,000	34.2	5,601,000	42,000	38.0	1,594,000
East	154,000	38.2	5,879,000	18,000	39.3	708,000
South West	123,000	27.6	3,398,000	29,000	34.8	1,010,000
South Central	21,000	24.6	517,000	6,000	33.5	201,000
South East	255,000	38.7	9,862,000	4,000	37.2	149,000

Part I

Southwest Missouri Center

The soil fertility experiments on small grains reported in this bulletin were established on Baxter silt loam and Gerald silt loam in 1960. The Baxter silt loam is a mature forest soil. The Gerald silt loam is a prairie soil with a claypan at about 12 inches. These soils and related Series represent a large portion of the soils of southwest and south central Missouri. They are acid and low in available phosphorus and potash. The soil test values of the two soil areas selected for the experiments are given in Table 3.

Table 3 shows that the soils were very low in available phosphorus and were quite acid. The potassium levels were unexpectedly high but due to the low phosphorus levels, little plant material had been removed, thereby permitting exchangeable potassium to accumulate. Potassium values on plots receiving phosphorus but no potassium fertilizers decreased rapidly, indicating the potassium-supplying power of the soils was low.

TABLE 3--INITIAL SOIL TEST VALUES OF SMALL GRAIN RESEARCH AREAS ON BAXTER AND GERALD SILT LOAMS

Soil Type	O.M. %	P_2O_5* lbs.	K lbs	Mg lbs	Ca lbs	pH H_2O	pH salt	Me** H	CEC
Baxter silt loam	2.5	15	415	225	950	5.1	4.6	4.5	8.4
Gerald silt loam	2.3	13	375	280	1750	5.6	5.0	4.0	10.1

* Brays strong extracting solution.
** Determined with old buffer solution. The solution developed in 1965 would give about twice this quantity of H.

PROCEDURES

Calcium limestone was applied at a rate of 4 tons per acre to both experimental areas in 1960. An additional six tons per acre of magnesium limestone were applied in the summer of 1965 due to the results of soil tests on samples taken at that time. The experimental plots were seven feet wide and 100 feet long and arranged in a randomized plot design with three replications. A recommended variety of each grain was planted, the variety not necessarily constant during the period of the studies.

All starter fertilizers were applied with the seeds; the quantity at no time reduced germination but in dry falls, seed on plots receiving starter fertlizers was somewhat slower in emerging than that on plots receiving no fertilizer. Starter fertilizers in this study included quantities of plant nutrients greater than those often described as "starter." Starters in this study included amounts of nutrients sufficient to supply most of the needs of the growing crop.

Harvesting was done with a self propelled combine, the grain from each plot being collected in separate tagged bags and weighed. Yields were calculated on a 15.5 percent moisture basis.

The following studies were established in 1960: (1) Starter ratios and rates for wheat and spring oats; (2) water solubility of phosphorus in starters for wheat; (3) starters, sources, rates, and time of application of nitrogen on wheat, winter barley, and winter oats; and (4) methods of supplying phosphorus for wheat. The studies with spring oats and wheat were established on Gerald silt loam while those with winter barley and winter oats were on Baxter silt loam.

A hailstorm during the boot stage decreased yields in 1961 and a freeze May 5, 1963, destroyed the wheat, barley, and winter oats. In 1964 the winter oats were winter killed. "Take All" disease appeared in some years on wheat and was especially severe in 1967. The years, in which failures of a crop occurred, were not included when determining average annual yields.

The specific treatments used in each study are given in the corresponding table. All data obtained from the studies were subjected to analyses of variance and significant differences among the treatments were evaluated by Duncan's New Multiple Range Test. All numbers followed by the same letter in an individual table are not significantly different.

RESULTS AND DISCUSSION

Study of Starter Ratios and Rates for Wheat

This study was designed to determine the most desirable composition and quantity of starter fertilizer for wheat on soils of Southwest Missouri.

The data (Table 4) show that 40 + 40 + 40 gave an average annual yield of 37.7 bushels per acre, a yield that was significantly greater than that given by any other treatment. Omitting the phosphorus (40 + 0 +440) decreased the

TABLE 4--EFFECTS OF COMPOSITION AND QUANTITY OF STARTER FERTILIZERS FOR WHEAT

	Yield Bu./A	Soil Test Values - 1965	
		P_2O_5	K
Treatment	6 yr. Avg.	lbs/A	lbs/A
1. No fertilizer	17.5 e	30 d	127 ab
2. 40+40+0	33.8 b	69 abc	108 ab
3. 40+0+40	23.0 d	46 bcd	175 a
4. 40+40+40	37.7 a	84 a	177 a
5. 20+20+20	32.8 b	49 abcd	133 ab
6. 10+10+10	25.4 c	41 cd	93 ab
7. 334 lbs. 3-12-12	32.1 b	82 ab	154 ab
8. 200 lbs. 5-20-20	33.7 b	73 abc	187 a
9. 334 lbs. 4-12-4	31.9 b	86 a	142 ab
10. 167 lbs. 8-24-8	34.3 b	83 ab	63 b
LSD .05	2.2	34	94

average annual yield by 14.7 bushels per acre and leaving out the potassium (40 + 40 + 0) decreased the average yield by only 3.9 bushels per acre. Decreasing the nitrogen by 30 pounds per acre (10 + 40 + 40, i.e. 200 lbs. 5-20-20) reduced the average annual yield by only 4.0 bushels per acre.

These results show that phosphorus was the most critical nutrient affecting yields of wheat but nitrogen and potassium were also necessary for the optimum yield. 10 pounds per acre of N were not adequate. Applying 20 + 20 + 20 instead of 40 + 40 + 40 reduced the yield by 4.9 bushels per acre; however, this treatment slightly decreased soil test phosphorus and potassium from the 40 + 40 + 40 treatment (not statistically significant), indicating that the limiting nutrient in this starter was nitrogen. The 40 + 40 + 40 and 10 + 20 + 20 starters produced significant increases in soil test phosphorus and potassium. This suggests the possibility that a 40 + 20 + 20 starter would have produced the optimum yield more economically.

Water Soluble Phosphates in Starter Fertilizers for Wheat

The objective of this study was to determine the effect of water solubility of phosphate carriers in starter fertilizers for wheat in southwest Missouri.

The results (Table 5) show that the 50 percent water soluble phosphate carrier was significantly better than the 5 percent soluble material only. Also, there were no significant differences among any of the other carriers. All of the starters increased yields significantly over the no fertilizer treatment. All of the starters significantly increased the soil test values for phosphorus and potassium four years after the beginning of the study.

The average annual yields for all treatments varied considerably, ranging from 21 bushels per acre in 1961 and 1967 to 53 bushels per acre in 1965. Variations were caused by weather conditions and disease. The high average yield of 53 bushels per acre in 1965 (the highest treatment yield was 60.2 bushels per

TABLE 5--THE EFFECT OF WATER SOLUBILITY OF PHOSPHATES IN STARTER FERTILIZERS FOR WHEAT

Treatment	Yield Bu./A 6 yr. Avg.	Soil Test Values 1965 P_2O_5 lbs/A	Soil Test Values 1965 K lbs/A
1. No Fertilizer	19.0 c	27 b	117 b
2. 40+40+40(95% H_2O sol. phos.)	37.8 ab	78 a	160 a
3. 40+40+40(50% H_2O sol. phos.)	38.9 a	68 a	180 a
4. 40+40+40(5% H_2O sol. phos.)	35.7 b	88 a	153 a
5. 40+40+40(NH_4NO_3, Cal., Meta., KCl)	36.5 ab	61 a	170 a
6. 40+40+40(NH_4NO_3, 45% Super, KCl)	36.6 ab	79 a	167 a
7. 40+40+40(NH_4NO_3, 21-53-0, KCl)	36.2 ab	62 a	167 a
LSD .05	2.7	28	40

acre) indicated that the 40 + 40 + 40 starter could produce good yields of wheat when no adverse conditions were present.

Time and Rate of Nitrogen Applications for Wheat

The objectives of this study were to determine the optimum rate and optimum time to top dress nitrogen on wheat grown on the soils of southwest Missouri. The nitrogen carrier was ammonium nitrate. All plots received 200 pounds of 5-20-20 as starter except plots receiving no treatment.

The data (Table 6) show that although the highest average yield was produced by topdressing 33 pounds of N per acre on March 15, this was not significantly better than any other time during the winter months. Topdressing 33 or 66 pounds of N at seeding was not better than 33 pounds N per acre in the winter or spring. Topdressing 33 pounds N at seeding in addition to the 10 pounds N per acre in the starter was not as good as applying a total of 40 pounds of N per acre at planting time, as was reported in the study of water soluble phosphates. In this study average annual yields ranged from 21 bushels per acre in 1967 to 43 bushels per acre in 1964. The highest treatment yield was 51.0 bushels per acre in 1965, produced by treatments 8 and 10 in Table 6. This yield was not significantly different from the ones obtained with other treatments, with the exception of 1, 2 and 3.

Forty pounds of P_2O_5 and K_2O per acre, applied annually in the starter, significantly increased the soil test values of phosphorus in most cases and of potassium in all cases.

TABLE 6--EFFECT OF RATE AND TIME OF TOPDRESSING NITROGEN ON YIELDS OF WHEAT

Treatment	Yield Bu./A 6 Yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs./A	Soil Test Values, 1965 K lbs./A
1. No Fertilizer	14.6 e	34 c	135 b
2. 10 lbs. N (starter)	29.4 d	72 b	190 a
3. 33 lbs. N at planting	29.5 d	101 a	187 a
4. 66 lbs. N at planting	32.0 cd	89 ab	178 a
5. 33 lbs. N Dec. or Jan.	34.9 abc	100 a	175 a
6. 66 lbs. N Dec. or Jan.	34.9 abc	77 ab	185 a
7. 33 lbs. N Feb.	35.9 ab	76 ab	193 a
8. 66 lbs. N Feb.	35.5 ab	85 ab	188 a
9. 33 lbs. N March 1	36.7 ab	74 ab	172 a
10. 33 lbs. N March 15	37.6 a	90 ab	182 a
11. 33 lbs. N April 1	35.0 abc	86 ab	187 a
12. 33 lbs. N April 15	33.7 bc	93 ab	205 a
LSD .05	3.0	23	29

Sources and Time of Applying Nitrogen as a Topdressing for Wheat

The objective of this study was to determine the best nitrogen carrier to use as a topdressing and the best time to apply this carrier to wheat on the soils of southwest Missouri. Test plots received 200 pounds per acre of 5-20-20 as starter fertilizer.

Results (Table 7) from this study show no significant differences in yields of wheat due to differences in nitrogen carriers. No difference was noted between winter and spring applications of these carriers. A slight increase occurred for March 1 applications of NH_4NO_3 and $(NH_4)_2SO_4$ but not for Solution 32. Starter only (10 + 40 + 40) produced a significant increase of 10.5 bushels per acre over no fertilizer. Thirty-three pounds of N in addition to the starter increased the yield significantly (4.6 bushels/A). Annual applications of the starter significantly increased the soil test phosphorus and potassium after four years. The average annual yields in this study ranged from 21 bushels per acre in 1961 to 47 bushels per acre in 1965. The highest single treatment yield was 53 bushels per acre in 1965 from treatments 3 and 5, Table 7.

High Rates of Nitrogen and Phosphorus for Wheat

The objectives of this study were to determine the effectiveness of minor elements, and of large applications of nitrogen and phosphorus on yields of wheat in southwest Missouri. The treatments were designed to apply phosphorus in starter only and starter annually after plowing down 400 pounds P_2O_5 in 1960. Three levels of nitrogen as ammonium nitrate other than that in the starter

TABLE 7--THE EFFECT OF SOURCE AND TIME OF APPLICATION OF NITROGEN AS A TOPDRESSING FOR WHEAT

Treatment*	Yield Bu./A 6 Yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs/A	Soil Test Values, 1965 K lbs/A
1. No Fertilizer	23.4 c	34 b	185 b
2. Starter only (10 lbs. N)	33.9 b	94 a	285 a
3. 33 lbs. N as Urea Applied in Dec. or Jan.	38.6 a	95 a	255 a
4. 33 lbs. N as Urea March 1	38.6 a	88 a	230 a
5. 33 lbs. N as Solution 32 Applied in Dec. or Jan.	38.6 a	94 a	238 a
6. 33 lbs. N as Solution 32 Applied March 1	37.6 a	113 a	247 a
7. 33 lbs. N as NH_4NO_3 March 1	39.0 a	105 a	271 a
8. 33 lbs. $(NH_4)_2SO_4$ March 1	38.7 a	91 a	266 a
LSD .05	2.6	37	65

*All plots received starter except those in treatment one.

were to be used and three of the treatments were to include a minor element mixture containing boron, molybdenum, zinc, copper, manganese, cobalt, and magnesium. The results of the study are given in Table 8.

The data show (Table 8) that the annual application of 40 lbs. P_2O_5 in the starter supplied enough phosphorus to produce the highest yields of wheat. However, the nitrogen (10 lbs.) in the starter apparently was inadequate for high yields because the 66 pounds N topdressed in March gave a significant increase in yield over starter only. Higher rates of N were not effective in increasing wheat yields.

The heavy plowdown applications of P_2O_5 were not effective in increasing yields over annual applications of phosphorus in the starter.

Addition of the minor element mixture had no effect on wheat yields in this study.

Plowing down 400 pounds of P_2O_5 per acre in 1960 significantly increased the soil test phosphorus above the level produced by annual applications of 40 pounds per acre after four years, but had no effect on yields of wheat. The starter fertilizer, after four years, had significantly increased the soil test phosphorus and potassium over that of the plots receiving no treatment.

The average annual yields in this study ranged from 12 bushels per acre in 1967 to 52.5 bushels per acre in 1965.

TABLE 8--EFFECTS OF MINOR ELEMENTS AND HIGH RATES OF NITROGEN AND PHOSPHORUS ON YIELDS OF WHEAT

Treatment*	Yield Bu./A 6 Yr. Avg.	Soil Test Values 1965 P_2O_5 Lbs./A	Soil Test Values 1965 K Lbs./A
1. No Fertilizer	20.8 c	35 c	132 c
2. Starter only (10+40+40)	32.3 b	99 b	242 a
3. 66 lbs. N	36.5 a	90 b	178 b
4. 66 lbs. N +400 lbs. P_2O_5	36.5 a	192 a	185 b
5. 66 lbs. N +400 lbs. P_2O_5 + Minor Elements**	36.8 a	155 a	165 b
6. 100 lbs. N +400 lbs. P_2O_5 + Minor Elements	34.5 ab	170 a	172 b
7. 132 lbs. N +400 lbs. P_2O_5 + Minor Elements	31.8 b	182 a	162 b
$LSD_{.05}$	2.7	44	28

*All plots excepting those getting no fertilizer received a 10 + 40 + 40 starter fertilizer annually.

**The mixture contained 10 lbs. borax, 10 lbs. sinc sulfate, 40 lbs. copper sulfate, 5 lbs. manganese sulfate, 1 lb. cobalt sulfate, 1 oz. sodium molybdate, 10 lbs. magnesium sulfate, and 25 lbs. gypsium. The mixture was applied at the rate of 100 lbs./Acre.

TABLE 9--THE EFFECT OF DIFFERENT RATIOS AND RATES OF STARTER FERTILIZERS AND ADDITIONAL NITROGEN AND PHOSPHORUS ON YIELDS OF SPRING OATS

Treatments	Yields Bu./A 7 Yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs/A	K lbs/A
1. No Fertilizer	23.4 d	35 d	220 a
2. 160 lbs. 12-12-12	36.7 ab	65 d	277 a
3. 250 lbs. 8-24-8	37.3 ab	173 ab	193 b
4. 250 lbs. 8-0-8	30.9 c	38 d	322 a
5. 250 lbs. 8-24-0	35.8 ab	175 a	200 b
6. 250 lbs. 8-16-8	38.8 a	138 bc	223 a
7. 250 lbs. 8-0-8 (400 lbs. P_2O_5 plowdown 1961)	36.2 ab	116 c	215 ab
8. 250 lbs. 8-24-8 (Topdress at planting)	34.4 b	165 ab	253 a
	2.8	34	106

Fertilizers for Spring Oats

The objectives of this study were to determine: (1) a suitable ratio and rate of starter fertilizer, (2) the best method of supplying phosphorus, and (3) the advantage of supplying additional nitrogen for spring oats on the soils of southwest Missouri. The results of this study are given in Table 9.

Adverse weather conditions and an unusually wet site for this study contributed to low average oat yields. The highest average yield of 38.8 bushels per acre was produced by 20 + 40 + 20 supplied by 250 pounds of 8-16-8. This yield was not significantly different from other treatments where phosphorus was applied as starter or was plowed down as superphosphate in 1961. Smaller amounts of P_2O_5 in the starter produced the same yield as 20-40-20 and did not increase the soil test phosphorus as did 40 pounds or 60 pounds of P_2O_5. The 19 + 19 + 19 starter produced only 2.1 bushels per acre less (not significant) than 20 + 40 + 20 and did not significantly increase the soil test phosphorus. In all cases P_2O_5 in the starter increased soil test phosphorus; 40 and 60 pounds per acre produced significant increases.

Potassium did not prove to be a limiting element in this study and in the soil test, potassium did not appear to be related to quantities of K_2O in the starter. If weather conditions had permitted higher yields, potassium in the starter might have been beneficial.

The 33 pounds N applied in addition to the 20 pounds N in the starter did not increase yields in this study.

TABLE 10--EFFECT OF DIFFERENT STARTER RATIOS AND RATES ON YIELDS OF BARLEY

Treatments	Yield Bu./A 6 yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs./A	 K lbs./A
1. No Fertilizer	26.8 d	70 cd	208 ab
2. 40+40+ 0	41.4 b	148 a	167 b
3. 40+ 0+40	32.5 c	46 d	298 a
4. 40+40+40	47.1 a	109 abc	275 ab
5. 20+20+20	45.5 ab	70 cd	230 ab
6. 10+10+10	43.6 ab	42 d	187 b
7. 334 lbs. 3-12-12	46.7 a	97 abcd	255 ab
8. 200 lbs. 5-20-20	45.2 ab	88 abcd	213 ab
9. 334 lbs. 4-12-4	47.5 a	144 ab	245 ab
10. 167 lbs. 8-24-8	47.7 a	117 abc	205 ab
LSD .05	3.9	55	94

Starter Fertilizer Rates and Ratios for Barley

This study was undertaken to determine the proper starter ratio and rate for barley on the soils of southwest Missouri. During the course of the study, winter killing was often severe, giving quite variable yields from year to year.

The data (Table 10) show that all starters carrying N + P + K gave significant yield increases over starter containing no P, indicating that phosphorus was a necessary constituent. However, the quantity of P_2O_5 needed was not great. The highest yield of 47.7 bushels per acre was produced by a 13 + 40 + 13 starter (167 lbs. 8-24-8) while the 10 + 10 + 10 starter produced 43.6 bushels per acre, which was not a significant difference. Forty + 40 + 40 produced 47.1 bushels per acre, indicating that more than 10 + 10 + 10 would not be necessary under the conditions of this study. In contrast, the soil test phosphorus increased from 42 pounds per acre on the 10 + 10 + 10 plots to 109 pounds per acre on the plots receiving the 40 + 40 + 40.

Potassium could be a limiting element under some conditions but small quantities were sufficient in the starter; 40 + 40 + 0 produced 41.4 bushels per acre while 10 + 40 + 10 (334 lbs. 4-12-4) gave a yield of 47.5 bushels per acre. A soil test value of 167 pounds K per acre on the 40 + 40 + 0 plots was undoubtedly a limiting value. The 10 + 10 + 10 did not increase the soil test potassium but did significantly increase the yield over 40 + 40 + 0.

The 10 + 10 + 10 would be the most economical fertilizer in the study. The soil phosphorus level of 70 pounds of P_2O_5 per acre on the no fertilizer plots is considerably higher than that found on other Baxter silt loam areas of the farm. This level plus the 10 pounds P_2O_5 in the 10 + 10 + 10 starter was sufficient to produce yields not significantly different than those produced by larger quantities of P_2O_5.

Rate and Time of Nitrogen Applications for Barley

The objectives of this study were to determine the best rate and time for applying nitrogen as a topdressing to barley on the soils of southwest Missouri. Two hundred pounds of 5-20-20 were applied to all plots except those getting no fertilizer. The nitrogen carrier in all cases was ammonium nitrate.

Yields of barley (Table 11) were quite variable over the seven years of the study as winter injury was often a problem. Average annual yields ranged from 59.0 bushels per acre in 1967 to 30.4 per acre in 1965 when much winter killing occurred. The severest injury was on the plots receiving the high nitrogen treatments.

The 10 + 40 + 40 starter fertilizer increased yields 18.6 bushels per acre over no fertilizer and 33 pounds N applied in December increased the yield by another 6.2 bushels per acre. Thirty-three pounds of N applied in March or February gave comparable increases. Sixty-six pounds of N proved to be excessive in all cases.

TABLE 11--EFFECT OF RATE AND TIME OF NITROGEN APPLICATION ON YIELDS OF BARLEY

Treatments	Yield Bu./A 6 Yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs/A	K lbs/A
1. No Fertilizer	27.6 f	75 a	208 a
2. Starter only (10 lbs. N)	46.2 cd	70 a	185 a
3. 33 lbs. N at seeding	46.2 cd	94 a	243 a
4. 66 lbs. N at seeding	41.3 e	134 a	237 a
5. 33 lbs. N in Dec. or Jan.	52.3 ab	127 a	230 a
6. 66 lbs. N in Dec. or Jan.	45.9 d	99 a	252 a
7. 33 lbs. N in Feb.	51.6 ab	79 a	215 a
8. 66 lbs. N in Feb.	45.1 d	87 a	223 a
9. 33 lbs. N March 1	52.9 a	111 a	238 a
10. 33 lbs. N March 15	52.6 a	96 a	238 a
11. 33 lbs. N April 1	49.9 abc	122 a	247 a
12. 33 lbs. N April 15	48.8 bcd	105 a	248 a
LSD .05	3.4	60	72

The P_2O_5 and K_2O in the starter were sufficient to supply plant needs without significantly increasing the soil test values of these nutrients after four applications. The phosphorus level of 75 pounds per acre of P_2O_5 on the plots receiving no starter (treatment 1 in Table 11) is considerably higher than the original soil test value of 15 pounds per acre P_2O_5 for Baxter silt loam. Apparently the area on which this experiment was placed had received applications of phosphorus prior to the purchase of the farm. A study presented earlier on starter ratios and rates for barley indicated that a starter somewhat lower in phosphorus than 40 pounds P_2O_5 per acre would be just as effective in producing optimum yields of barley on this soil.

Starter Ratios and Rates for Winter Oats

The objectives of this study were to determine a suitable ratio and rate of starter fertilizer for winter oats in southwest Missouri.

The response of winter oats (Table 12) to starter fertilizers followed the same pattern as wheat and barley. N, P, and K were necessary for good yields but the quantity needed of each was relatively small. Ten + 10 + 10; 20 + 20 + 20; and 40 + 40 + 40 did not give significantly different yields. All gave about 50 bushels per acre. The 40 + 40 + 40 significantly increased the phosphorus in the soil test over that in tests of plots receiving the other two treatments. In fact, all starters with 40 pounds of P_2O_5 per acre increased soil test phosphorus significantly more than all other treatments. Forty + 40 + 0 and 40 + 0 + 40 gave the same yields, which were significantly greater than yields with no fer-

TABLE 12--EFFECT OF DIFFERENT RATIOS AND RATES OF STARTER FERTILIZERS ON YIELDS OF WINTER OATS

Treatments	Yields Bu./A 5 Yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs/A	Soil Test Values, 1965 K lbs/A
1. No Fertilizer	37.1 d	35 b	153 a
2. 40+40+0	45.3 c	126 a	170 a
3. 40+ 0+40	42.7 c	47 b	253 a
4. 40+40+40	50.1 ab	113 a	241 a
5. 20+20+20	51.8 a	53 b	158 a
6. 10+10+10	48.5 abc	47 b	195 a
7. 334 lbs. 3-12-12	49.9 ab	120 a	245 a
8. 200 lbs. 5-20-20	47.1 abc	105 a	305 a
9. 334 lbs. 4-12-4	48.6 abc	101 a	190 a
10. 167 8-24-8	44.8 bc	100 a	180 a
LSD .05	5.3	44	140

tilizer and significantly less than those with a complete fertilizer, 10 + 10 + 10 for instance, showing that phosphorus and potassium were both necessary to produce optimum yields.

The quantity of potassium revealed by soil test was not significantly increased by potassium in the starter fertilizer in this study. Wide differences in soil test values of potassium within a replication made a large increase necessary for significance.

During the period of the study, yields varied widely from year to year. Winter injury often reduced stands. Stands were completely killed in 1963 and 1964. Average annual yields ranged from 58.7 bushels per acre in 1967 to 31.0 bushels per acre in 1965. Winter killing was often most severe on the more heavily treated plots. In 1965 the highest yield of 43.5 bushels per acre was produced on plots receiving the 10 + 10 + 10 starter and the lowest yield of 11.2 bushels per acre was on the plots receiving 40 + 40 + 0. Forty + 40 + 40 produced only 18.4 bushels per acre, which was not significantly different from the yield produced by the 40 + 40 + 0 treatment.

Rate and Time of Nitrogen Applications on Winter Oats

The objectives of this study were to determine the optimum rate and time of applying nitrogen as a topdressing to winter oats in southwest Missouri. With the exception of the control plot that received no fertilizer, all plots received 200 pounds per acre of 5-20-20 as the starter fertilizer. The nitrogen carrier was ammonium nitrate.

Yields of winter oats (Table 13) were greatly affected by weather conditions as was mentioned in the above study with winter oats. Winter injury often occurred and was especially severe in 1965 on the plots that received heaviest treatment. The highest yield, 50.6 bushels per acre in 1965, was produced on the plots receiving no treatment. The lowest yield, 16.4 bushels per acre, was produced on the plots receiving starter plus 66 pounds of N at planting.

The rather high levels shown in soil tests for phosphorus and potassium on the no treatment plots, 64 pounds of P_2O_5 and 262 pounds of K per acre, made yield results difficult to evaluate. This experimental area was adjacent to the barley research site mentioned previously, which apparently had received some fertilizer before the farm was purchased. The plots receiving only the starter produced 50.7 bushels per acre. Those producing the highest average yield, 56.0 bushels per acre, not significantly larger, received 33 pounds N in addition, applied March 15. In general, spring topdressing of 33 pounds N were better than fall or winter applications. Sixty-six pounds N gave no yield increases over 33 pounds N and in some cases the yields were significantly lower.

Soil test phosphorus was increased significantly by applying starter in all cases but one. The starter fertilizer did not significantly increase soil test values for potassium, primarily because of the wide range in these values within a replication.

TABLE 13--EFFECT OF DIFFERENT RATES AND TIME OF NITROGEN APPLICATIONS ON YIELDS OF WINTER OATS

	Treatments	Yield Bu./A 5 Yr. Avg.	Soil Test Values, 1965 P_2O_5 lbs./A	K lbs./A
1.	No Fertilizer	48.5 cd	64 b	262 b
2.	Starter only (10 lbs. N)	50.7 abcd	138 a	298 ab
3.	33 lbs. N at planting	51.3 abcd	153 a	345 ab
4.	66 lbs. N at planting	49.3 bcd	165 a	393 a
5.	33 lbs. N in Dec. or Jan.	52.2 abc	132 a	360 ab
6.	66 lbs. N in Dec. or Jan.	45.5 d	125 a	265 b
7.	33 lbs. N in Feb.	49.1 bcd	129 a	332 ab
8.	66 lbs. N in Feb.	49.6 bcd	134 a	280 ab
9.	33 lbs. N March 1	52.6 abc	148 a	367 ab
10.	33 lbs. N March 15	56.0 a	123 a	302 ab
11.	33 lbs. N April 1	55.0 ab	171 a	363 ab
12.	33 lbs. N April 15	55.3 ab	114 ab	287 ab
	LSD .05	5.5	55	107

CONCLUSIONS
Southwest Missouri Center

The seven years of small grain studies at the southwest Missouri Center have given data from which the following conclusions can be drawn:

1. Forty pounds of N per acre is adequate for producing optimum yields of wheat and spring oats. In the case of wheat, this can be as starter fertilizer drilled in with the seed or about 10 pounds per acre applied as starter and the remainder topdressed, preferably in March. Barley and winter oats will respond well to only 10 pounds of N in the starter fertilizer. An additional 30 pounds of N can be topdressed in March to advantage if winter killing has not been severe.

2. Forty pounds of P_2O_5 per acre is probably more than adequate when applied as a starter drilled in with the seed. This quantity should supply sufficient phosphorus for optimum yields of all grains and gradually increase the available phosphorus level of the soil. The most economical quantity would probably be 25 to 30 pounds of P_2O_5 per acre.

3. Forty pounds of K_2O is also more than adequate if drilled as a starter with the seed. This quantity will, in all probability, produce optimum yields of the

small grains and gradually increase the exchangeable potassium level of the soil.

4. A starter fertilizer composed of 40 + 30 + 30 drilled in with the seed when planting wheat or spring oats should give profitable yields of these crops. Barley and winter oats would probably do better with a lower quantity of plant food, possibly a 20 + 20 + 20.
5. Hazards of winter killing still make winter oats a questionable crop to grow in southwest Missouri. Winter barley could be grown with less danger than winter oats.
6. The small grains in these studies were grown on the same plots, receiving the same treatment each year. If these grains were grown after a crop such as corn or sorghum, a good starter might be a 20 + 30 + 30, to be followed by a topdressing of 30 pounds N per acre in March.

Part II A
Southeast Missouri (Delta) Center

Considerable soil fertility research with wheat had been done in southeast Missouri prior to 1960 at the Sikeston Research Field and on numerous cooperator farms. With the acquisition of the Delta Center at Portageville and the Clarkton Research Field near Clarkton, studies were initiated to more adequately determine the nutrient requirements of wheat on southeast Missouri soils. Use of farmer cooperators was restricted to special cases or areas.

PROCEDURES

The 4 small grain fertility studies on the Delta Center research fields were on: (1) starter ratios and rates, (2) sources and rates of nitrogen, (3) time of application of nitrogen, and (4) methods of application of phosphorus. The studies were started in 1960 at Sikeston and Portageville and in 1961 at Clarkton. One crop was lost on the Sharkey Clay at Portageville due to high water. Plots were 7 feet in width and 100 feet long, and treatments were applied in a randomized block design of three replications. Plots were harvested by a combine, the grain caught in individually numbered bags, and yields were calculated as bushels per acre at 15.5 percent moisture.

Table 14 gives the initial soil test values of the areas on which the experiments were established. These values were high in most cases, which apparently explains the rather low response to starter fertilizers in some of the studies. All

TABLE 14--INITIAL SOIL TEST VALUES ON EXPERIMENT STATION FIELDS WHEAT FERTILITY STUDIES - SOUTHEAST MISSOURI

Location		O.M. %	Pounds Per Acre P_2O_5	K	Mg	Ca	Salt pH	Me H	Cation Exchange Capacity
Sikeston Dexter Sandy Loam	0-7"	2.4	350	475	93	1470	5.0	2.0	6.7
	8-14"	1.5	182	431	106	1285	5.2	1.0	5.3
Portageville Salix Silt Loam	0-7"	1.5	128	230	480	2175	5.0	3.0	10.7
	8-14"	1.5	165	240	330	1550	4.5	3.0	8.1
Portageville Sharkey Clay	0-7"	2.4	189	455	940	6500	5.5	4.0	24.7
	8-14"	1.0	170	455	940	5800	5.5	3.0	22.0
Clarkton Dexter Sand	0-7"	1.0	240	135	30	0	4.4	3.5	3.8
	8-14"	1.0	98	135	44	0	4.4	4.0	4.3

studies were on continuous wheat, with each plot getting the prescribed treatment each year. The straw was turned under after each harvest in preparation for planting again in the fall. Recommended varieties were used in each case, not necessarily the same at all locations or for the entire period of the study.

RESULTS AND DISCUSSION

Starter Ratios and Rates for Wheat

The objectives of this study were to determine the best ratio and rate of a starter fertilizer to use for wheat on the major soils of southeast Missouri. The study was carried out with a uniform application of 66 pounds of N applied as a topdressing in March. This rate of nitrogen and time of application were used since earlier studies had indicated that these were often the optimum conditions for applying nitrogen for wheat. Yields varied considerably at different locations and in different years. Average annual yields varied from 35.2 bushels per acre in 1963 to 52.4 bushels per acre in 1964 as Sikeston, from 25.9 bushels per acre in 1967 to 70.6 bushels per acre in 1961 on the Sharkey Clay at Portageville, from 39.6 bushels per acre in 1967 to 70.1 bushels per acre in 1961 on the Salix Silt Loam at Portageville, and from 19.8 bushels per acre in 1962 to 44.0 bushels per acre in 1965 at Clarkton.

A summary of these studies is given in Table 15. At Sikeston and Portageville, where soil test values for phosphorus and potassium were high, no significant yield increases were obtained with the different ratios and quantities of P_2O_5 and K_2O in the starter fertilizer. It is evident that with soils of these and similar series having soil phosphorus tests ranging from 128 pounds to 350 pounds of P_2O_5 per acre in the surface 7 inches of soil, no responses could be expected from additional phosphorus applied in starter fertilizer. Likewise, with soil potassium test values ranging from 230 pounds to 475 pounds of K per acre, no increase in yield could be expected with additional potassium applied in starter fertilizer. In contrast, yields with the Dexter Sand at Clarkton were significantly reduced (4.2 bushels/A) when the phosphorus was omitted in the starter or when the application of the phosphorus was delayed and applied as a topdressing. This was true even though the soil test value for phosphate was 240 pounds per acre.

The soil test value for potassium would appear to be low at 135 pounds per acre, yet additional K applied in the starter fertilizer did not increase wheat yields in this experiment. The fact that subsoil K was also 135 pounds per acre could indicate that potassium was not limiting wheat yields in this study.

Time of Application of Nitrogen for Wheat

The objective of this study was to more clearly define the time for top dressing nitrogen fertilizer on wheat in southeast Missouri. With the exception of treatment 2 in which the starter was also top dressed in the spring, all plots re-

TABLE 15--STARTER FERTILIZER RATIOS AND RATES FOR WHEAT IN SOUTHEAST MISSOURI

Yields: Bushels of Wheat per Acre

Treatments: Starter	Treatments: Top Dressed in March	Sikeston Dexter Sandy Loam 5 Year Average	Portageville Sharkey Clay 5 Year Average	Portageville Salix Silt Loam 6 Year Average	Clarkton Dexter Sand 6 Year Average
9+36+36	66 lbs. N	42.0 a	49.1 a	50.0 b	34.5 b
None	75+36+36	42.4 a	46.4 a	51.6 ab	32.1 c
9+ 0+36	66 lbs. N	41.4 a	48.6 a	51.2 ab	31.2 c
9+36+ 0	66 lbs. N	41.4 a	49.2 a	51.3 ab	35.4 ab
6+24+24	69 lbs. N	42.9 a	47.5 a	51.9 a	35.0 ab
12+48+12	63 lbs. N	42.4 a	46.6 a	52.0 a	36.1 a
	LSD (.05)	1.5	2.9	1.6	1.4

ceived a starter fertilizer of 9 + 36 + 36 at seeding. A constant rate of 66 pounds of N as ammonium nitrate per acre was used, time of application being the variable. Average annual yields ranged from 40.0 bushels per acre in 1963 to 59.3 bushels per acre in 1965 on the Dexter Sandy Loam at Sikeston, from 21.7 bushels per acre in 1967 to 75.3 bushels per acre in 1961 on the Sharkey Clay at Portageville, from 36.5 bushels per acre in 1967 to 65.7 in 1961 on the Salix Silt Loam at Portageville, and from 8.2 bushels per acre in 1961 to 33.2 bushels per acre in 1965 on Dexter Sand at Clarkton. A summary of this study is given in Table 16.

At Sikeston on the Dexter Sandy Loam no significant difference in yield resulted when the time of application of nitrogen ranged from January to April. Top dressing the nitrogen at seeding time gave significantly less (2.2 bushels per acre) than other applications.

Applying nitrogen to wheat on the Sharkey Clay in the spring (March or April) was significantly better than fall or winter applications by an average of 4.2 bushels per acre. Evidently, denitrification was an active process on this cold, poorly drained soil during the winter months. The same process was apparently active on the Salix silt loam because March was a significantly better time than fall or winter on this soil by 3.4 bushels per acre.

The application of nitrogen to wheat on Dexter Sand was significantly better in March than in January (1.6 bushels per acre) or in the fall (1.6 bushels per acre and 4.9 bushels respectively). Apparently, leaching of nitrogen fertilizer occurs on this sandy soil during the winter and fall months. Applying nitrogen in March was significantly better than applying it in April by 5.4 bushels per acre.

Rates of Nitrogen for Wheat on Soils With a High Phosphorus Level

The objective of this study was to determine the nitrogen level to use in conjunction with a high soil phosphorus level. Four hundred pounds of P_2O_5 were plowed down on all plots and a 9 + 36 + 36 starter was applied with the seed at planting time. All nitrogen rates were applied in March.

The average annual yields ranged from 35.5 bushels per acre in 1961 to 52.3 bushels per acre in 1965 on the Dexter Sandy Loam at Sikeston, from 21.5 bushels per acre in 1967 to 53.3 bushels per acre in 1961 on Sharkey Clay at Portageville, from 30.7 bushels per acre in 1967 to 68.3 bushels per acre in 1961 on the Salix Silt loam at Portageville, and from 14.5 bushels per acre in 1962 to 33.7 bushels per acre in 1966 on the Dexter sand at Clarkton. A summary of this study is given in Table 17.

On the Dexter Sandy Loam at Sikeston 66-pound and 100-pound applications of N per acre were not significantly better than 33 pounds N, but 66 pounds of N gave significantly better yield than 132 pounds by 3.3 bushels per acre. Thirty-three pounds of N gave significantly better yield than no N by 7.4 bushels per acre. Under the conditions of this study, 33 pounds of N would have been the most economical rate of Nitrogen to use on the Dexter Sandy Loam.

TABLE 16--TIME OF NITROGEN APPLICATION FOR WHEAT ON EXPERIMENT STATION FIELDS - SOUTHEAST MISSOURI

Treatments Starter 9+36+36		Yields: Bushels per acre Sikeston Dexter Sandy Loam 5 Year Average	Portageville Sharkey Clay 5 Year Average	Portageville Salix Silt Loam 6 Year Average	Clarkton Dexter Sand 6 Year Average
66 lbs. N at Seeding		45.8 b	43.9 b	48.6 bc	23.5 c
66 lbs. N in January		47.8 a	43.8 b	48.0 c	26.8 b
66 lbs. N in March		47.6 a	48.4 a	51.7 a	28.4 a
66 lbs. N in April		48.5 a	46.9 a	49.6 abc	23.0 c
66 lbs. N in March w/minor elements		46.8 ab	49.1 a	51.0 ab	27.9 ab
	LSD (.05)	1.6	2.2	2.5	1.4

TABLE 17--RATES OF NITROGEN ON SOILS WITH HIGH PHOSPHORUS LEVEL
EXPERIMENT STATION FIELDS-SOUTHEAST MISSOURI

Treatments			Yields: Bushels per Acre			
Plow Down	Starter	lbs. N in March	Sikeston Dexter Sandy Loam 5 Year Average	Portageville Sharkey Clay 5 Year Average	Portageville Salix Silt Loam 6 Year Average	Clarkton Dexter Sand 6 Year Average
400 P_2O_5	9+36+36	None	35.4 c	22.5 d	39.5 c	16.1 d
400 P_2O_5	9+36+36	33	42.9 ab	33.1 c	45.5 a	25.6 c
400 P_2O_5	9+36+36	66	45.2 a	40.1 b	46.9 a	29.2 b
400 P_2O_5	9+36+36	100	44.1 ab	43.9 a	44.6 ab	31.4 a
400 P_2O_5	9+36+36	132	41.9 b	43.5 a	41.9 b	31.8 a
		LSD (.05)	2.4	2.0	2.9	1.6

The 100-pound and 132-pound rates of N on the Sharkey Clay at Portageville were not significantly different in their influence on yields of wheat. However, the 100-pound rate was significantly better than the 66-pound rate by 3.8 bushels per acre and was 10.8 bushels per acre better than the 33-pound rate. The 66-pound rate gave 7.0 bushels per acre better yield than the 33-pound rate and 17.6 bushels per acre better yield than no nitrogen. Under the conditions of this study, 66 pounds per acre of N would be a profitable investment. The next increment of 33 pounds of N would produce only 3.8 more bushels per acre but would be profitable.

The response of wheat to applied nitrogen on the Salix Silt Loam was similar to that on the Dexter Sandy Loam. Yields from the 33, 66, and 100-pound rates were not significantly different, but the highest average yield of 46.9 bushels per acre was produced by the 66 pound rate. The 132 pound rate produced a yield significantly lower than the 66 pound rate, but the 100 pound rate did not. All nitrogen rates produced significantly higher yields than no nitrogen, but the 33 pound rate produced the greatest difference (6.0 bushels per acre). The next increment of 33 pounds N produced only 1.4 bushels per acre more than the 33 pound rate, an increase neither statistically significant nor economically profitable.

The higher rates of N were more necessary on the Dexter Sand than on the Salix Silt Loam. Lower soil organic matter content and chance for loss of fertilizer nitrogen by leaching on the Dexter Sand would indicate a higher rate for this soil. The 33 pound N rate was significantly better than no nitrogen by 9.5 bushels per acre and the 66 pound rate was significantly better than the 33 pound rate by 3.6 bushels per acre. This increase would have been an economical increase as well. The 100 pound N rate was significantly better than the 66 pound rate by 2.2 bushels per acre, an increase of questionable economic importance. The 132 pound rate of N was no better than the 100 pound rate in this study.

Rates of Nitrogen for Wheat Applied With and Without Starter Fertilizers

The objectives of this experiment were to determine the effectiveness of starter fertilizers and the benefit of spring top-dressed nitrogen on yields of wheat grown on some representative soils of southeast Missouri. The average annual yields ranged from 35.0 bushels per acre in 1963 to 49.8 bushels per acre in 1965 on the Dexter Sandy Loam, from 18.3 bushels per acre in 1967 to 48.7 bushels per acre in 1961 on the Sharkey Clay, from 28.9 bushels per acre in 1967 to 60.8 bushels per acre in 1961 on the Salix Silt Loam, and from 8.3 bushels per acre in 1962 to 30.7 bushels per acre in 1963 on the Dexter Sand. A summary of the data is given in Table 17.

On the Dexter Sandy Loam, with the initial level of P_2O_5 and K being relatively high, the use of starter fertilizers did not increase the yield of wheat either with or without added nitrogen. Thirty-three pounds N significantly increased yields (8.8 bushels per acre) over no nitrogen, and 66 pounds N increased yields by 4.0 bushels per acre over the 33 pound N application. Rates of N higher than 66 pounds did not give significant yield increases on this soil.

The Sharkey Clay, which also contained a high initial level of P and K, did not respond to the use of a starter fertilizer. Top-dressed nitrogen, however, increased yields significantly up to and including 100 pounds N per acre. Thirty-three pounds N increased yields by 10.3 bushels per acre, 66 pounds N increased yields 6.9 bushels per acre over the 33 pound rate, and 100 pounds gave a further increase of 4.5 bushels per acre over the 66 pound rate. All of these yield increases would have been economically worthwhile under conditions of this study. As mentioned previously, the wet conditions of the Sharkey Clay increases the need for nitrogen fertilizer.

The Salix Silt Loam, another soil with a high initial level of P and K, did not respond to starter fertilizers. This soil was well drained and required less nitrogen than the Sharkey Clay to give optimum yields. Thirty-three pounds of N gave a significant increase in yield of 10.9 bushels per acre over the no nitrogen treatment. Higher rates of N than the 33 pound rate did not significantly increase yields on this soil.

Starter fertilizers gave increased yields over no starter on the Dexter Sand, possibly because of the low K value of this soil. Additional nitrogen also gave increased yields over starter fertilizer on the Dexter Sand. Nine + 36 + 36 gave a significant increase of 4.7 bushels per acre over no starter while an additional 33 pounds of N increased yields another 9.7 bushels per acre. Using 66 pounds of N with the starter increased yields another 2.9 bushels per acre and 132 pounds N with the starter boosted yields another 3.5 bushels per acre over the 66 pounds N rate. These increases probably would be profitable with nitrogen costing less than $0.10 per pound. Thirty-three pounds N alone increased yields by 12.2 bushels per acre over no treatment but to get further increases in yield, the starter fertilizer was necessary. Use of the starter with the 33 pounds N produced 2.2 bushels per acre more than the nitrogen alone but when 66 pounds N were applied alone no increase over the 33 pounds of N alone was produced. Using the starter with the 66 pounds of N, however, gave 2.9 bushels per acre more than starter plus 33 pounds N. It is apparent that on this soil the addition of starter and/or spring-applied N up to 66 pounds per acre would be profitable.

Part II B

Southeast Missouri Cooperator Farms

Experiments were carried out on farms of three cooperators to study conditions not encountered on Experiment Station land. The conditions were a relatively infertile sandy loam on the Burge Farm near Malden, a relatively infer-

TABLE 18--RATES OF NITROGEN WITH AND WITHOUT STARTER FERTILIZER ON EXPERIMENT STATION FIELDS - SOUTHEAST MISSOURI

Treatment		Yields: Bushels per Acre			
Starter	lbs. N in March	Sikeston Dexter Sandy Loam 5 Year Average	Portageville Sharkey Clay 5 Year Average	Portageville Salix Silt Loam 6 Year Average	Clarkton Dexter Sand 6 Year Average
1. None	None	31.3 c	19.8 d	33.3 c	10.0 f
2. 9+36+36	None	32.9 c	21.9 d	35.4 c	14.7 e
3. None	33	40.3 b	29.7 c	45.3 ab	22.2 d
4. 9+36+36	33	41.4 b	32.7 c	47.0 ab	24.4 c
5. None	66	44.5 a	36.7 b	47.7 ab	20.9 d
6. 9+36+36	66	45.3 a	39.4 b	48.3 a	27.3 b
7. 9+36+36	100	45.5 a	42.6 a	46.4 ab	28.2 b
8. 9+36+36	132	44.8 a	45.5 a	42.8 b	30.8 a
	LSD (.05)	1.7	3.4	4.9	2.0

tile Waverly silt loam on the Kalkbrenner farm near Poplar Bluff, an infertile Calhoun silt loam on the Griffin farm near Qulin, and soil subjected to land forming, both cutting and filling, on the Roth farm near Malden. The studies were of one year duration on the Burge (1961) and Griffin (1966) farms, four years on the Kalkbrenner farm (1961-64), and two years on the Roth farm (1961-62). The treatments were on different plots each year. The soil test values on all plots before treatment are given in Table 19. The treatments used on the Burge, Kalkbrenner, and Roth farms were the same as those on the Experiment station soils; plot size and experimental design were also the same. Treatments and experimental design were different on the Griffin farm.

RESULTS AND DISCUSSION

Starter Ratios and Rates for Wheat on Cooperators' Farms

The objectives of this study were to determine the optimum ratio and rate of starter fertilizers for wheat under some widely varying soil conditions. The data are given in Table 20. A uniform rate of 66 pounds of N was used on all treatments, the variable being the ratio and quantity of the starter fertilizer.

In most cases the soil phosphorus and potassium were at adequate levels to produce optimum yields without potassium and phosphorus in the starter. On the Kalkbrenner and Roth farms in 1962, there is evidence that omitting phosphorus in the starter fertilizer statistically reduced yields in comparison with a complete starter fertilizer applied in the fall (38.4 bu. vs. 42.7 bu. for Kalkbrenner and 9.9 bu. vs. 32.6 bu. per acre for the cut area on the Roth farm). There is also evidence that when yield increases were attributed to phosphorus in the starter, it was applied at a rate of 36 or more pounds per acre. In cases where phosphorus in the starter produced a yield increase, the increase was reduced if plant nutrients equal in quantity to those used as the starter in the fall were top dressed on the wheat in March. The degree of reduction depended on the phosphorus level in the soil.

Rates of Nitrogen for Wheat on Soils High in Phosphorus

The objective of this study was to determine the optimum nitrogen level for wheat grown on soils with a high phosphorus level. The high phosphorus level was obtained by plowing down 400 pounds P_2O_5 per acre in the summer and using a 9 + 36 + 36 starter fertilizer on all plots at planting time. The variables were different rates of N as ammonium nitrate applied in March. The data are given in Table 21.

In every case but one, significant increases in yields of wheat were obtained by use of nitrogen in addition to that in the starter fertilizer. The exception was in 1961 when the filled area which contained nearly 2.0 percent organic matter to a depth of 14 inches did not respond to added nitrogen. The quantities of nitrogen giving profitable responses varied with the organic matter level of the

TABLE 19--INITIAL SOIL TEST VALUES OF SOIL ON COOPERATOR FARMS
WHEAT FERTILITY STUDIES - SOUTHWEST MISSOURI

Location			O.M. %	Pounds Per Acre P_2O_5	K	Mg	Ca	Salt pH	Me H	Cation Exchange Capacity
Burge (Malden)		0-7"	1.1	117	325	290	1305	6.4	0	4.9
Dexter sandy loam	1961	7-14"	0.7	48	295	260	1000	6.2	0	4.0
Kalkbrenner		0-7"	1.8	44	290	620	1860	6.3	2.0	9.6
Waverly silt loam	1961	7-14"	1.2	10	220	650	1750	6.1	2.0	9.4
Kalkbrenner		0-7"	1.8	44	290	620	1860	6.3	2.0	9.6
Waverly silt loam	1962	7-14"	1.2	10	220	650	1750	6.1	2.0	9.4
Kalkbrenner		0-7"	1.8	58	90	660	3000	6.0	1.0	11.5
Waverly silt loam	1963	7-14"	1.1	19	40	540	2800	6.1	1.0	10.5
Kalkbrenner		0-7"	1.7	58	90	660	3000	6.0	1.0	11.5
Waverly silt loam	1964	7-14"	1.1	19	40	540	2800	6.1	1.0	10.5
Roth - Filled		0-7"	2.0	110	420	1200	2810	6.0	0.5	13.1
Sharkey clay loam	1961	7-14"	1.8	61	270	870	2810	5.8	1.0	11.9
Roth - Filled		0-7"	2.0	110	420	1200	2810	6.0	0.5	13.1
Sharkey clay loam	1962	7-14"	1.8	61	270	870	2810	5.8	1.0	11.9
Roth - Cut		0-7"	1.0	9	315	1200	3765	5.9	1.5	16.3
Sharkey clay loam	1961	7-14"	0.9	5	305	1120	2810	6.1	1.0	12.9
Roth - Cut		0-7"	1.0	9	315	1200	3765	5.9	1.5	16.3
Sharkey clay loam	1962	7-14"	0.9	5	305	1120	2810	6.1	1.0	12.9
Griffin Calhoun silt loam	1966	0-7"	1.6	22	60	180	1500	4.2	4.0*	8.5

* Determined by new buffer

TABLE 20--STARTER RATIOS AND RATES FOR WHEAT ON COOPERATOR FARMS - SOUTHEAST MISSOURI

Yields: Bushels per Acre

Treatments: Starter	Treatments: Top Dressed in March	Burge Dexter Sandy Loam 1961	Kalkbrenner Waverly Silt Loam 1961	1962	1963	1964	Roth Sharkey Clay Loam: Fill 1961	Fill 1962	Cut 1961	Cut 1962
9+36+36	66 lbs. N	30.5 b	44.2 b	42.7 ab	47.0 a	40.1 a	55.0 a	29.2 a	53.8 b	32.6 a
None	75+36+36	34.4 a	48.3 ab	38.6 b	45.0 a	37.1 b	57.3 a	28.3 a	56.5 ab	15.9 c
9+ 0+36	66 lbs. N	35.1 a	47.7 ab	38.4 b	45.0 a	39.6 a	54.7 a	25.0 b	57.3 ab	9.9 d
9+36+ 0	66 lbs. N	35.0 a	47.5 ab	43.9 a	46.3 a	37.4 b	55.3 a	28.6 a	59.1 a	31.8 a
6+24+24	69 lbs. N	35.8 a	48.6 a	38.9 b	47.0 a	40.8 a	55.7 a	28.3 a	58.5 a	23.9 b
12+48+12	63 lbs. N	31.8 b	44.2 b	41.7 ab	50.0 a	39.7 a	56.5 a	28.6 a	54.0 b	32.0 a
	LSD (.05)	1.8	3.5	4.4	5.2	1.7	5.4	1.4	4.0	3.0

TABLE 21--RATES OF NITROGEN ON SOILS WITH HIGH PHOSPHORUS LEVEL ON COOPERATOR FARMS IN SOUTHEAST MISSOURI

Yields: Bushels per Acre

Treatments: Plow Down P_2O_5	Treatments: Starter	Treatments: Lbs. N in March	Burge Dexter Sandy Loam 1961	Kalkbrenner Waverly Silt Loam 1961	1962	1963	1964	Roth Sharkey Clay Loam: Fill 1961	Fill 1962	Cut 1961	Cut 1962
400 lbs.	9+36+36	None	11.8 d	25.5 d	27.8 b	52.0 b	20.9 c	49.6 a	30.0 c	38.7 e	16.8 d
400 lbs.	9+36+36	33	28.3 c	33.4 c	39.0 a	57.0 a	30.9 b	48.0 a	36.5 b	51.4 d	32.9 c
400 lbs.	9+36+36	66	36.8 b	43.3 b	44.7 a	54.0 ab	36.5 a	50.0 a	38.7 a	61.7 c	40.2 b
400 lbs.	9+36+36	100	39.4 a	45.7 b	39.1 a	51.0 b	37.5 a	48.0 a	36.2 b	65.9 b	42.0 ab
400 lbs.	9+36+36	132	39.5 a	52.5 a	42.1 a	53.7 ab	37.0 a	50.6 a	37.3 ab	69.0 a	43.5 a
		LSD (.05)	2.2	5.5	6.9	3.4	2.2	2.7	1.5	2.0	3.0

soil. The Dexter Sandy Loam, the Waverly Silt Loam used in 1961, and the cut area of the Sharkey Clay Loam responded to higher nitrogen levels than did the sites having higher organic matter levels. On the Dexter Sandy Loam, 33 pounds of N gave 16.5 more bushels per acre than no top dressing, 66 pounds N gave 8.5 more than 33 pounds and 100 pounds N gave 2.6 bushels more than 66 lbs. N.

An application of 33 pounds of N on the Waverly Silt Loam used in 1961 gave an increase of 7.9 bushels per acre over no top-dressed nitrogen and 66 pounds N produced 9.9 bushels per acre more than 33 pounds. The yield response to 100 pounds N was not significant but 132 pounds N gave a significant increase of 9.2 bushels per acre over the 66 pound rate. This increase could be considered an economical one.

The Waverly Silt Loam soil used in 1962 gave a significant response only to the 33 pound N rate. This yield increase was 11.2 bushels per acre. The Waverly Silt Loam site used in 1963 also responded to the 33 pound rate of N, but the yield increase was only 5.0 bushels per acre, compared with the 11.2 bushels per acre the previous year. The level of production of all plots was considerably higher in 1963 than in any other year of the study. In 1964, 33 pounds of N produced 10.0 bushels per acre more than no nitrogen and 66 pounds N gave an additional significant increase of 5.6 bushels per acre.

The filled area of the Sharkey Clay Loam did not respond to applied nitrogen in 1961 but the location used in 1962 responded similarly to the Waverly Silt Loam. Thirty-three pounds N produced 6.5 bushels per acre more than no top dressing and 66 pounds N gave a significant increase of 2.2 bushels per acre. The 2.2 bushel increase was of no great economic importance. Higher rates of N did not give significant yield differences.The cut areas of the Sharkey Clay Loam, however, gave good yield increases up to and including 132 pounds N per acre. The significant yield increases were as follows: 132 pounds$>$ 100 pounds N by 3.1 bushels per acre; 100 pounds N$>$ 66 pounds N by 4.2 bushels per acre; 66 pounds$>$ 33 pounds N by 10.3 bushels per acre; and 33 pounds N$>$ no N by 12.7 bushels per acre. All yield increases would have been economical ones in 1961. In 1962, the over-all yields were not as high, but significant yields were produced by top-dressed nitrogen up to 100 pounds per acre. Thirty-three pounds N produced 16.1 bushels per acre more than no nitrogen, 66 pounds N produced 7.3 bushels per acre more than 33 pounds N, and 100 pounds N produced 2.2 bushels per acre more than 66 pounds N. The last figure was statistically significant, but barely economically so.

Time of Nitrogen Application for Wheat

The objective of this study was to determine the best rates of nitrogen for widely varying soil conditions in southeast Missouri. The variable in the study was time of application. The application was 66 pounds of N as ammonium nitrate. All plots received 9 + 36 + 36 as a starter fertilizer at seeding. Table 22 gives results.

The Dexter Sandy Loam responded most favorably to a March application of nitrogen. The March application was 9.1 bushels per acre better than January and 19.1 bushels per acre better than either April or fall applications. Evidently, the nitrogen applied at planting was lost by leaching in this sandy soil. The nitrogen applied in April was either too late for the wheat to benefit from it, or was leached out of the root zone by spring rains. The application of minor elements had no effect on yields on this sandy soil.

Time of application of nitrogen on the Waverly silt loam was of lesser importance than on the Dexter sandy loam. Statistically in all cases March was as good a time as at seeding and two times out of four January and April were as good as March. The trend, however, was in favor of March applications as March was better on the average by 4.1 bushels compared with January and also 4.1 bushels better when compared with April applications.

The data for the Sharkey Clay Loam, on the other hand, show that March is the most favorable time to apply nitrogen on this soil; both cut and fill locations responded in the same way. Top dressing the nitrogen in the fall at seeding time, however, was as good as March application in all but one instance while in three times out of four, April applications were less favorable than March applications.

Effect of Rates of Nitrogen and Starter Fertilizer on Yields of Wheat

The objectives of this study were to determine the optimum rate of nitrogen to use with and without starter fertilizer on widely varying soil conditions in southeast Missouri. The starter fertilizer was 9 + 36 + 36 and the nitrogen carrier in each instance was ammonium nitrate.

Data from the Dexter Sandy Loam show that both nitrogen and a complete fertilizer were necessary to produce acceptable yields of wheat on this soil; however, nitrogen was the major factor in increasing yields. Starter alone did not produce a significant yield increase but 33 pounds of N alone doubled the yield produced when the starter was applied alone. The combination of starter and 33 pounds of N gave a yield of 5.6 bushels per acre over the nitrogen alone. Sixty-six pounds N alone did not give an increase over 33 pounds of N plus starter, but starter plus the 66 pounds N gave an increase of 5.0 bushels per acre over the 66 pounds of N alone. Increasing the nitrogen to 100 pounds of N in addition to the starter did not significantly increase yields but 132 pounds of N with the starter gave a significant increase of 5.5 bushels per acre over the starter and 66 pounds of N, which would have been an economical practice under the conditions of this study.

The responses to nitrogen and starter fertilizers on the Waverly Silt Loam had the same relationship as in the case of the Dexter Sandy Loam, with the exception of the site used in 1963, which apparently had a high initial fertility

TABLE 22--TIME OF NITROGEN APPLICATION FOR WHEAT ON COOPERATOR FARMS - SOUTHEAST MISSOURI

Treatments 9+36+36 Starter on all Plots	Yields: Bushels per acre								
	Burge Dexter Sandy Loam	Kalkbrenner Waverly Silt Loam				Roth Sharkey Clay Loam			
						Fill		Cut	
	1961	1961	1962	1963	1964	1961	1962	1961	1962
66 lbs. N at Seeding	19.4 c	45.1 ab	38.5 a	48.7 a	42.6 a	50.6 bc	32.5 a	52.2 a	33.3 a
66 lbs. N January	29.7 b	44.0 b	38.6 a	46.0 ab	37.2 c	48.0 c	32.7 a	54.1 a	31.3 ab
66 lbs. N March	38.1 a	48.2 a	44.9 a	48.0 a	41.0 ab	51.2 b	31.7 ab	54.4 a	31.8 ab
66 lbs. N April	19.9 c	45.5 ab	38.6 a	42.3 b	39.2 b	50.8 bc	28.5 c	51.6 a	30.3 b
66 lbs. N March Minor elements	39.4 a	47.5 a	43.9 a	44.7 ab	40.9 ab	54.7 a	30.4 b	53.0 a	29.1 b
LSD (.05)	1.8	3.1	6.3	4.9	1.8	2.9	1.8	3.4	2.5

TABLE 23--EFFECT OF RATES OF NITROGEN AND STARTER FERTILIZER ON YIELD OF WHEAT ON COOPERATOR FARMS IN SOUTHEAST MISSOURI

Treatments		Yields: Bushels per acre								
		Burge Dexter Sandy Loam	Kalkbrenner Waverly Silt Loam				Roth Sharkey Clay Loam			
							Fill		Cut	
Starter	lbs N in March	1961	1961	1962	1963	1964	1961	1962	1961	1962
None	None	10.6 e	19.7 f	20.4 d	43.0 a	17.1 d	52.0 ab	25.3 c	32.9 d	8.9 d
9+36+36	None	12.1 e	22.9 ef	25.0 cd	44.0 a	19.8 d	53.4 a	28.1 c	37.5 d	19.7 b
None	33	24.7 d	28.2 de	27.0 bcd	46.7 a	29.8 c	52.2 ab	35.9 ab	44.2 c	10.9 cd
9+36+36	33	30.3 c	33.9 cd	37.0 ab	53.0 a	32.2 bc	53.4 a	35.6 ab	51.5 b	30.0 a
None	66	31.0 c	36.7 bc	35.7 abc	48.7 a	34.6 b	50.8 abc	36.0 ab	48.6 bc	12.9 c
9+36+36	66	36.0 b	42.9 b	41.5 a	50.3 a	38.9 a	51.4 abc	37.5 a	58.1 a	32.8 a
9+36+36	100	37.7 b	49.3 a	41.9 a	49.7 a	40.6 a	47.0 bc	37.0 ab	60.9 a	30.9 a
9+36+36	132	41.5 a	53.9 a	43.3 a	51.0 a	39.8 a	46.6 c	34.3 b	62.7 a	33.2 a
	LSD .05	2.9	6.3	10.5	9.0	4.0	5.0	2.8	6.0	2.4

level. In 1961 and 1964, starter alone did not produce significant yield increases while 33 pounds of N did produce significant yield increases of an average of 10.6 bushels per acre over no fertilizer. Adding starter to the 33 pounds of N did not significantly increase yield but increasing the nitrogen to 66 pounds of N without the starter gave significant yield increases over the 33 pounds of N alone.

The starter plus 66 pounds of N gave a significant yield increase over 66 pounds N alone in 1964, but in 1961, it was necessary to apply 100 pounds of N with the starter to get a significant increase over the 66 pound N application. Applications greater than 100 pounds of N did not give yield increases either year.

In 1962 it was necessary to add the combination of 9 + 36 + 36 plus 33 pounds of N to get a significant yield increase over no fertilizer. This yield was also significantly greater than starter alone by 12 bu./A. In this year, it took starter plus 66 pounds of N to produce a significantly yield greater than 33 pounds N alone. Quantities of N greater than 66 pounds did not significantly increase yields in 1962.

The filled area of the Sharkey Clay Loam did not respond to starter fertilizer either year and responded to 33 pounds of N only in 1962. Other applications of nitrogen either had no effect on yields or decreased them at the 132 pound rate. The 1961 experimental site on the cut area of the Sharkey Clay Loam did not respond to starter fertilizer but the site used in 1962 gave an increase of 10.8 bushels per acre to an application of 9 + 36 + 36. Thirty-three pounds of N alone in 1961 gave significant increases of 6.7 bushels per acre over starter alone, while on the site used in 1962, this application gave a decrease of 8.8 bushels per acre. The combination of starter plus 33 pounds of N gave significant yield increases over 33 pounds of N alone of 7.3 bushels per acre in 1961 and 20.0 bushels per acre in 1962. 66 pounds N alone gave no improvement over 33 pounds alone in 1962, or over the combination of starter and 33 pounds N in 1961. However, the combination of starter and 33 pounds N in 1961 was better by 9.5 bushels per acre than the 66 pounds N alone. Greater quantities of nitrogen than 33 pounds did not increase yields even when combined with starter fertilizer in 1962.

Effect of Lime, Nitrogen, and Starter Fertilizers on Yields of Wheat

The objective of this study was to determine the relationships between limestone, starter fertilizers, and nitrogen and yields of wheat on soils with very low fertility and pH levels. The representative soil was of the Calhoun series with the soil test values as shown in Table 19. Treatments were: Zero and two tons of fine (200 mesh) St. Genevieve limestone; zero and 9 + 36 + 36 starter fertilizer and zero, 33, 50, 66, and 100 pounds of N top-dressed per acre. A randomized block, split plot experimental design with three replications was used with limestone as the main block. The results are given in Table 24.

TABLE 24--EFFECT OF LIMESTONE, STARTER FERTILIZER, AND NITROGEN ON YIELD OF WHEAT GROWN ON CALHOUN SILT LOAM SOIL

Limestone Study	Bu./A	Starter Study	Bu./A
No Limestone	26.6 a	No Starter	13.9 b
2T Fine Limestone	27.7 a	9 + 36 + 36	40.3 a
$LSD_{.05}$	2.5	$LSD_{.05}$	2.5

Nitrogen Study	Bu./A	Limestone x Starter Study	Bu./A
No N	22.7 c	0 Limestone x 0 Starter	15.3 c
33 lbs N	26.2 bc	0 Limestone x 9+36+36	37.8 b
50 lbs N	26.6 bc	2T Limestone x 0 Starter	12.5 c
66 lbs N	31.3 a	2T Limestone x 9+36+36	42.8 a
100 lbs N	28.9 ab	$LSD_{.05}$	3.5
$LSD_{.05}$	3.9		

Nitrogen x Starter Study

	Bu./A		Bu./A
0 N x 0 Starter	17.5 d	0 N + Starter	27.9 c
33 lbs N x 0 Starter	10.9 e	33 lbs N + Starter	41.5 ab
50 lbs N x 0 Starter	13.6 de	50 lbs N + Starter	39.7 b
66 lbs N x 0 Starter	16.0 de	66 lbs N + Starter	46.5 a
100 lbs N x 0 Starter	11.8 de	100 lbs N + Starter	45.9 a
		$LSD_{.05}$	5.6

Considered alone, limestone had no significant effect on yield. On the other hand, both starter and nitrogen gave significant yield increases. The starter increased yields from 13.9 to 40.3 bushels per acre. Nitrogen at the rate of 66 pounds per acre increased yields by 8.6 bushels per acre over the zero N rate.

There were significant limestone x starter and nitrogen x starter interactions, with the limestone x starter interaction being the greater of the two. The addition of 9 + 36 + 36 starter increased yields from 15.3 to 37.8 bushels per acre. Application of two tons of limestone increased the yield significantly to 42.8 bushels per acre. Sixty-six and 100 pounds N per acre gave slightly higher average yields, but the increases were not statistically significant. Where no starter was used, additional nitrogen had very little effect on yields, but when starter was used with 33 pounds N per acre, yields were increased to 41.5 bushels per acre. There was very little lime x nitrogen interaction in the analysis, indicating that nitrogen and starter were very necessary for the growth of wheat on this soil and that the effectiveness of the starter was enhanced by a moderate application of limestone.

CONCLUSIONS

Southeast Missouri

Soil fertility research on wheat at the Delta Center since 1960 has given data from which the following conclusions can be drawn:

1. Applications of nitrogen influence wheat yields more than any other fertilizer unless the soil has a very low phosphorus level.
2. Sixty-six pounds N per acre is the optimum rate to use on silt loam and sandy loam soils.
3. On clay or sandy soils 100 pounds N per acre will give optimum wheat yields most years.
4. March is the most favorable time to apply nitrogen on all soil types. Nitrogen may be applied to silt loam or sandy loam soils in other months (October to April) with only a small reduction in yield.
5. Where land forming is being done, filled areas need little nitrogen, if any. Cut areas will likely respond to as high as 100 pounds N per acre where the entire plowed layer has been removed.
6. Good yields of wheat can be produced at surprisingly low phosphorus soil test values. Soil test values of about 50 pounds of P_2O_5 per acre produced nearly optimum yields when nitrogen was applied at 66 peunds per acre. Applying 9 + 36 + 36 starter in addition did not always increase yields significantly. This was true where the pH was 5.8 or above.
7. Where soils have a very low phosphorus test value (22 lbs. P_2O_5 per acre) and a low salt pH(4.2), yields of wheat can be more than doubled by a starter fertilizer such as 9 + 36 + 36. The yield could be further increased by applying limestone (2T fine limestone) to such soils.
8. Good yields of wheat can be produced on soils testing as low as 60 pounds of K per acre. The addition of starter containing potash did not increase yields significantly in the two cases in the study where soil test K was 60 and 90 pounds per acre.

Part III

Weldon Spring Center

Soil fertility studies on wheat were begun at the Weldon Spring Center in 1955 shortly after the area was acquired by the University of Missouri. The studies included source, rate, and time of nitrogen application on continuous wheat and source, rate, and time of nitrogen applications on corn crops preceding wheat in corn-corn-wheat, and corn-wheat rotations. Experiments were not laid out in a randomized design, but three replications were used in most cases. In this report, statistical analyses were made on the data collected since 1960 or 1962, based on the assumption that treatments were properly randomized. This fact must be kept in mind when interpreting results of the analyses. All studies were made on Weldon Silt Loam. Representative initial soil test values are given in Table 25.

TABLE 25--INITIAL SOIL TEST VALUES ON THE EXPERIMENTAL AREAS OF WELDON SILT LOAM

O.M. %	P_2O_5 Lbs.	K Lbs.	Mg Lbs.	Ca Lbs.	Salt pH	H Me	CEC
1.8	40	280	280	2000	5.8	2.2	8.8

RESULTS AND DISCUSSION

Effect of Source, Rate, and Time of Application of Nitrogen on Continuous Wheat

This study was composed of 41 different treatments including no treatment, starter only, two rates of nitrogen applied in five different carriers, one rate of one carrier applied by different methods, and three dates of application. The average annual yields ranged from 28.7 bushels per acre in 1962 to 61.8 bushels per acre in 1966. The data obtained since 1962 are summarized in Table 26.

All yields that are followed by an "a" and underlined are not significantly different. However, many of these yields are also followed by a "b" and are,

TABLE 26--THE EFFECT OF SOURCE, RATE, AND TIME OF APPLICATION OF NITROGEN ON YIELDS OF WHEAT GROWN ON WELDON SILT LOAM
Yields: Bushels per acre, 6 yr. avg. 1962-7

Source and Rate of Nitrogen*		Time of Application: Seeding	December	March
Ammonium Nitrate	60 lbs.	47.1 defg	50.3 abc	49.6 abcd
	30 lbs.	44.0 hij	49.4 abcd	46.7 efgh
Ammonium Sulfate	60 lbs.	47.7 bcde	49.5 abcd	50.0 abcd
	30 lbs.	47.4 cdef	47.6 bcde	47.1 defg
Anhy. Ammonia	60 lbs.	50.6 ab	47.8 bcde	48.0 bcde
	30 lbs.	48.1 bcde	45.4 ghij	41.6 j
Solution 32	60 lbs.	50.4 abc	49.6 abcd	50.2 abc
	30 lbs.	48.4 abcd	45.7 fghi	45.8 fgh
Urea	60 lbs.	48.5 abcd	49.2 abcd	47.1 defg
	30 lbs.	47.8 bcde	46.6 efgh	45.2 ghi
Solution 41 60 lbs	Surface	48.9 abcd		
	Disced	50.4 abc		
	Deep	51.1 a		
Starter only		34.7 k		
No Fertilizer		33.3 k		
	$LSD_{.05}$	2.5		

*All plots received 10+60+30 starter. 3T lime, 180 lbs. P_2O_5 and 120 lbs. K_2O were plowed down in 1955. The nitrogen, other than that in starter, anhydrous ammonia, and solution 41, was top dressed.

therefore, not significantly different from many of the other yields which are followed by a "b", but not an "a".

Table 26 shows, with but two exceptions that: (1) all yields followed by an "a" were produced by 60 pounds N, (2) all carriers have produced their share of yields followed by an "a", and (3) the three dates of application were nearly equally effective. Ammonium nitrate and ammonium sulfate are more effective when applied at seeding; solution 32 was effective at all times; and urea was best when applied at seeding or in December. Solution 41 produced the same high yields when applied at seeding with all three methods of application. Since the soil was brought up to soil test in 1955, starter fertilizer did not increase the yield over that of the no fertilizer treatment. From this it can be inferred that phosphorus and potassium were present in adequate amounts.

Residual Nitrogen Effects on Yield of Wheat

The objectives of this study were to determine the effects on wheat yields in a corn, corn, wheat rotation of different rates and dates of nitrogen application. Rates of applying nitrogen as ammonium nitrate were zero, 60, 120, and 240 pounds per acre. The four different times of application that were compared were fall and spring on first or second year corn. In two cases, nitrogen was applied to wheat in the rotation at the rate of 30 and 60 pounds per acre. All crops received 10 + 40 + 40 starter. Plots were 13.3 feet wide and 100 feet long. One thousand pounds of rock phosphate and 120 pounds of K_2O were applied to all plots in 1955. The data obtained from this study since 1960 are given in Table 27. Although not part of the analyses, the average yields of corn for the several treatments are included in the table.

The results show several things:

(1) nitrogen is not readily leached from Weldon Silt Loam. When 240 pounds of N were applied to first year corn (Treatment 6) in the fall, the succeeding yields of corn were 96.3 and 78.8 bushels per acre, respectively, and the wheat yield was 32.4 bushels per acre. These yields are nearly equal to those produced when 120 pounds of N were applied in the fall on first and second year corn (Treatment 4). In this case the corresponding yields were 89.5, 82.3, and 33.0 bushels per acre. Again these yields closely equal those produced by Treatment 11, where the nitrogen was applied in the spring rather than in the fall.

(2) More than 60 pounds N are needed per acre to grow a crop of corn, although some of this nitrogen is used by the succeeding wheat crop. Where 60 pounds of N were applied on first and second year corn (Treatment 2) the yields were 69.8, 67.0, bushels of corn and 21.7 bushels of wheat per acre. These yields are considerably lower than those cited above where 120 pounds of N per acre were applied on both crops of corn.

(3) Thirty pounds of N on the wheat with 60 pounds of N per acre on both corn crops (Treatment 9) increased wheat yields by 14.4 bushels per acre (compare with Treatment 7). Applying another 30 pounds of N to the wheat increased yields by another 10 bushels per acre (Treatment 10).

TABLE 27--EFFECT OF TIME AND RATE OF NITROGEN ON YIELD OF WHEAT WHEN APPLIED TO PRECEDING CORN CROPS IN A CORN, CORN, WHEAT ROTATION ON WELDON SILT LOAM

Treatment	Yields Bu./Acre			
	Wheat 8 Yr. Avg.	1st Yr. Corn 7 Yr. Avg.	2nd Yr. Corn 7 Yr. Avg.	Total Corn
1. Starter only (10+40+40)	16.3 f	32.2	26.9	59.1
2. 60 lbs. N 1st yr. corn in fall, 60 lbs. N 2nd yr. corn	21.7 e	69.8	67.0	136.8
3. 60 lbs. N 1st yr. corn in fall, 0 N, 2nd yr. corn	19.5 e	68.1	34.1	102.2
4. 120 lbs. N 1st yr. corn in fall, 120 lbs. N 2nd yr. corn	33.0 c	89.5	82.3	171.8
5. 120 lbs. N 1st yr. corn in fall, 0 N, 2nd yr. corn	22.2 de	92.0	49.4	141.4
6. 240 lbs. N 1st yr. corn in fall, 0 N, 2nd yr. corn	32.4 c	96.3	78.8	175.1
7. 60 lbs. N 1st yr. corn in spring, 60 lbs. N 2nd yr. corn	24.4 d	74.8	68.1	142.9
8. 60 lbs. N 1st yr. corn in spring, 0 N, 2nd yr. corn	20.9 e	61.9	45.9	107.8
9. 60 lbs. N 1st yr. corn in spring, 60 lbs. N 2nd yr. corn, 30 lbs. N on wheat	38.8 b	74.1	69.7	143.8
10. 60 lbs. N 1st yr. corn in spring, 60 lbs. N 2nd yr. corn, 60 lbs. on wheat	49.3 a	72.7	72.6	145.3
11. 120 lbs. N 1st yr. corn in spring, 120 lbs. N 2nd yr. corn	31.2 c	85.4	79.9	165.3
12. 120 lbs. N 1st yr. corn in spring, 0 N, 2nd yr. corn	19.6 e	79.8	31.8	111.5
$LSD_{.05}$	2.8			

*All crops received 10+40+40 starter all years
Limestone, 1000 lbs. rock phosphate and 120 lbs. K_2O applied to experimental area in 1956.

(4) It is apparent that another treatment—120 pounds of N on each crop of corn and 60 pounds N on the succeeding wheat crop—would have been helpful. It is evident from the other data that this would be an economical practice on this type of soil.

Residual Nitrogen Effects on Yields of Wheat As Related to the Nitrogen Carrier

The objectives of this experiment were to determine the most effective rate of a given source of nitrogen on the yields of wheat when the nitrogen is applied to corn in a corn-wheat rotation. Eight different carriers applied at two different rates were used in the study. The soil was brought up to soil test at the beginning of the experiment in 1956. An 8 + 30 + 30 starter was used on all plots. The plots were 13.3 feet wide and 100 feet long. The data obtained from this study since 1960 are given in Table 28. The corn yields were not included in the analysis. The initial productivity of this experiment site was greater than that of the site used for the rotation experiment reported above. This was unfortunate in that some of the carrier effects could have been masked by the initial productivity of the soil.

The data show that in all cases the yield produced by 120 pounds of N of a given carrier was significantly greater than that produced by 60 pounds of N of that carrier. The increase was approximately 10 bushels per acre of wheat due to the additional 60 pounds supplied per acre to the corn. The increase in yield of

TABLE 28--EFFECT OF SOURCE AND RATE OF NITROGEN ON YIELD OF WHEAT WHEN APPLIED TO CORN IN A CORN-WHEAT ROTATION ON WELDON SILT LOAM

Treatment		Yields Bu./A Wheat 8 yr. Avg.	Yields Bu./A Corn 7 yr. Avg.
1. Ammonium Sulfate	60 lbs. N	30.6 cd	90.7
	120 lbs. N	42.9 a	100.4
2. Ammonium Nitrate	60 lbs. N	32.7 c	87.8
	120 lbs. N	43.5 a	102.6
3. Urea	60 lbs. N	33.3 c	92.1
	120 lbs. N	41.2 ab	104.0
4. Anhydrous NH_3	60 lbs. N	34.0 c	92.2
	120 lbs. N	42.7 a	103.6
5. Solution 32	60 lbs. N	33.4 c	85.5
	120 lbs. N	41.6 ab	103.9
6. No Nitrogen		29.2 d	65.9
7. No Nitrogen		32.7 c	68.3
8. Solution 41	60 lbs. N	32.0 cd	84.3
	120 lbs. N	38.4 b	94.4
9. Sodium Nitrate	60 lbs. N	33.6 c	88.3
	120 lbs. N	44.1 a	100.2
10. Calcium Nitrate	60 lbs. N	31.4 cd	89.7
	120 lbs. N	39.5 b	103.0
	LSD .05	4.3	

corn due to the additional 60 pounds of N was also approximately 10 bushels per acre. This would have been a highly profitable practice.

The effectiveness of source of nitrogen on yield of wheat when applied to the preceding crop of corn is given in Table 29. The results show that of the eight nitrogen sources, six of them were not significantly different from each other. Solution 41 and calcium nitrate were not significantly different from three of the others, i.e. ammonium sulfate, urea, and solution 32.

TABLE 29--EFFECT OF SOURCE OF NITROGEN ON YIELDS OF WHEAT WHEN APPLIED TO CORN IN A CORN-WHEAT ROTATION

Source		Yield Bu./A 8 Yr. Avg.
Sodium Nitrate		38.9 a
Anhydrous Ammonia		38.4 a
Ammonium Nitrate		38.1 a
Solution 32		37.5 ab
Urea		37.3 ab
Ammonium Sulfate		36.7 ab
Calcium Nitrate		35.4 b
Solution 41		35.2 b
No Nitrogen		30.9 c
	LSD .05	2.1

CONCLUSIONS
Weldon Spring Center

Results of the tests at Weldon Spring lead to the following conclusions for that area and soil types.

1. Sixty pounds of N per acre top dressed on wheat grown on Weldon Silt Loam of moderate fertility could be an economical rate. This would be true regardless of whether the preceding crop was wheat or corn.
2. Heavy applications of nitrogen can be made on Weldon Silt Loam without much danger of loss by leaching or denitrification.
3. The standard nitrogen carriers appear to be equally effective as nitrogen sources when applied to Weldon Silt Loam.
4. Weldon Silt Loam apparently does not lose fall applied nitrogen, either by leaching or denitrification. Its fairly heavy B horizon could prevent loss of nitrates by leaching during the winter, but would be open enough to prevent reducing conditions to develop.

Part IV
Bradford Research Farm

The Bradford Research Farm near Columbia was acquired by the University in 1960 and some soil fertility experiments on wheat and winter barley were begun in the fall of 1960. Others were started in the fall of 1961. Initial soil test values on the area's Mexico Silt Loam are given in Table 30.

The studies were similar in purpose to those initiated at the Southwest Missouri Center in 1960. The experimental design was a completely randomized block with 3 or 5 replications. Plots were seven feet wide and 100 feet long and were harvested by a combine. Grain from each plot was collected in numbered bags and yields were calculated in bushels per acre at 15.5 percent moisture. Recommended varieties were always planted but often differed from year to year.

TABLE 30--INITIAL SOIL TEST VALUES OF EXPERIMENTAL SITES BRADFORD RESEARCH FARM

	O.M. %	P_2O_5* Lbs/A	K Lbs/A	Mg Lbs/A	Ca Lbs/A	Salt pH	Me**	CEC
Range A[1]	2.2	192	310	310	4200	6.0	0.5	13.7
Range G[2]	1.8	112	110	200	3300	5.6	1.0	10.2
Range U[3]	2.3	67	250	380	5000	5.8	2.0	16.4

[1]Starter ratios and rates, solubility of phosphorus, rates of nitrogen studies of wheat on Range A

[2]Sources of nitrogen studies for wheat and barley on Range G

[3]Starter ratios and rates, solubility of phosphorus, rates of nitrogen studies for barley on Range U

*Brays strong extracting solution

**Determined by old buffer

After the six years of the studies, phosphorus and potassium soil test values have remained about the same on Range A and increased somewhat on Ranges G and U as determined by results of tests on composite soil samples taken from each range in the fall of 1967.

RESULTS AND DISCUSSION

Starter Ratios and Rates for Wheat and Barley

The objectives of this study were to determne the ratio and rates of starter fertilizers for wheat and winter barley on Mexico Silt Loam. Average annual yields for wheat ranged from 22.3 bushels per acre in 1965 to 60.6 bushels per acre in 1963. Average annual yields of barley ranged from 13.8 bushels per acre in 1965 to 79.9 bushels per acre in 1964. Results are given in Table 31.

Both wheat and winter barley responded to phosphorus and potassium in

TABLE 31--EFFECT OF STARTER RATIOS AND RATES ON YIELDS OF WHEAT AND BARLEY ON MEXICO SILT LOAM

	Yields: Bu./Acre	
Treatments	Wheat 6 Yr. Avg.	Barley 6 Yr. Avg.
1. No fertilizer	35.5 e	43.7 d
2. 40+40+ 0	44.7 bc	50.2 b
3. 40+ 0+40	41.3 d	50.2 b
4. 40+40+40	47.6 a	52.2 a
5. 20+20+20	47.2 a	49.1 b
6. 10+10+10	44.0 c	46.9 c
7. 334 lbs. 3-12-12	47.3 a	47.9 c
8. 200 lbs. 5-20-20	46.8 a	46.6 c
9. 334 lbs. 4-12-4	47.2 a	47.2 c
10. 167 lbs. 8-24-8	46.7 ab	49.0 b
LSD .05	2.0	.18

a starter fertilizer. Wheat made a greater response to phosphorus than to potassium. In the case of barley, response to these two nutrients appears to have been about the same.

Barley apparently responded to a higher rate of nitrogen than did wheat, giving a greater response to 40 + 40 + 40 than to 20 + 20 + 20 while wheat yields produced by these two fertilizers were not significantly different. In fact, a starter fertilizer containing 10 + 40 + 40 produced a six-year average wheat yield comparable to that produced by 40 + 40 + 40. The phosphorus and potassium levels were initially lower on the barley experimental areas, but the annual application of 40 pounds of P_2O_5 and K_2O was sufficient to increase these levels to a point where these nutrients were not limiting barley yields. This would indicate that barley did have the ability to respond to a larger application of nitrogen than wheat in this study.

Water Soluble Phosphates in Starter Fertilizers for Wheat and Barley

The objectives of this study were to determine the effectiveness of highly water-soluble phosphate carriers in starter fertilizers for wheat and barley on Mexico Silt Loam. The treatments and results of the study are given in Table 32. The average annual yields of wheat ranged from 17.1 bushels per acre in 1965 to 61.7 bushels per acre in 1963. The average annual yields of barley ranged from 14.8 bushels per acre in 1962 to 81.5 bushels per acre in 1964.

The fertilizers, except those containing urea, were equally effective in producing wheat and barley. The relatively high initial phosphorus in the soil of the experimental sites could have masked the effectiveness of certain phosphorus carriers due to differences in water solubility. Where urea was a component of fertilizer drilled in with the seed, yields of wheat and barley were significantly reduced; wheat by an average of 6 to 8 bushels per acre and barley by 3 to 6 bushels per acre. However, wheat yield reduction appeared to be related inversely to

TABLE 32--EFFECT OF SOLUBILITY OF PHOSPHATE CARRIERS ON YIELDS OF WHEAT AND BARLEY GROWN ON MEXICO SILT LOAM

Treatments	Wheat Yields: Bu./Acre 6 Yr. Avg.	Barley Yields: Bu./Acre 6 Yr. Avg.
1. No fertilizer	31.5 d	41.9 d
2. 40+40+40 (95% Water Sol. P_2O_5)	44.0 b	49.0 a
3. 40+40+40 (50% Water Sol. P_2O_5)	44.5 d	49.4 a
4. 40+40+40 (5% Water Sol. P_2O_5)	44.2 b	48.7 a
5. 40+40+40 (Blend NH_4NO_3, Cal. Meta., KCl)	44.0 b	48.4 a
6. 40+40+40 (Blend NH_4NO_3, 46% Superphos, KCl)	44.6 b	48.9 a
7. 40+40+40 (Blend Urea, 46% Superphos, KCl)	36.2 c	45.8 bc
8. 20+20+20 (Blend Urea, 46% Superphos, KCl)	38.2 c	45.2 c
9. 10+10+10 (Blend Urea, 46% Superphos, KCl)	38.1 c	42.7 d
10. 0 +40+40 (40 lbs. N as Urea top dressed after seeding)	48.1 a	47.6 ab
$LSD_{.05}$	2.0	1.9

the quantity of urea in the starter, the decrease being greatest at 40 pounds of N as urea and least at 10 pounds of N as urea. In the case of barley there was a reduction of three bushels per acre due to the fact that the carrier was urea instead of ammonium nitrate (40 lbs. N in each case). At the lower rate of nitrogen (10 + 10 + 10), the reduction of five bushels per acre could have been due to insufficient quantities of all three of the nutrients rather than any toxic effect of the urea itself. The fact that urea could be a good source of nitrogen for both wheat and barley was demonstrated by a plot top-dressed with urea which produced the highest yields of the experiment.

Rates of Nitrogen for Wheat and Barley

The objectives of this study were to determine the optimum quantities of nitrogen to top dress on stands of wheat and winter barley on Mexico Silt Loam. Rates of nitrogen tried included 10 pounds in the starter, and 33, 66, 100, and 132 pounds N per acre top dressed in March. Average annual yields of wheat ranged from 20.6 bushels per acre in 1965 to 70.1 bushels per acre in 1963. Average annual yields of barley ranged from 12.8 bushels per acre in 1965 to 76.8 bushels per acre in 1964. The results of this study are given in Table 33.

The data show that initial fertility levels of the experiment sites were relatively high in that the no treatment plots produced 38.7 and 43.4 bushels of wheat and barley, respectively. In the case of wheat, 10 + 40 + 40 banded

TABLE 33--EFFECT OF RATE OF NITROGEN APPLICATIONS ON YIELDS OF WHEAT AND BARLEY ON MEXICO SILT LOAM

Treatments	Yields: Bu./A Wheat 7 Yr. Avg.	Yields: Bu./A Barley 6 Yr. Avg.
1. No Fertilizer	38.7 c	43.4 d
2. Starter only (10+40+40)	46.4 ab	46.8 c
3. 33 lbs. N in March	47.0 a	53.3 ab
4. 66 lbs. N in March	47.0 a	55.1 ab
5. 100 lbs. N in March	44.6 b	55.6 a
6. 132 lbs. N in March	45.1 b	52.4 b
LSD .05	.18	2.7

*All plots received starter fertilizer except those receiving no fertilizer at all.

starter produced the highest yield. Further additions of nitrogen gave no significant yield increases and the higher rates significantly reduced yields. The starter increased barley yields to 46.8 bushels per acre and an additional 33 pounds N increased yields to 53.3 bushels per acre. Sixty-six and 100 pounds of N increased yields, but not significantly. An application of 132 pounds per acre tended to decrease yields.

Source and Time of Nitrogen Applications for Wheat and Barley

The objectives of this study were to determine the best carrier of nitrogen and the best time to apply it to wheat and barley grown on Mexico Silt Loam. A constant rate of 33 pounds N per acre was used in addition to the 10 pounds of N applied in the starter. Average annual yields of wheat ranged from 10.2 bushels per acre in 1965 to 65.4 bushels per acre in 1963. Average annual yields of barley ranged from 20.9 bushels per acre in 1965 to 69.8 bushels per acre in 1964. The results of the study are given in Table 34.

As was the case with the study reported immediately above, the initial soil fertility level was relatively high. The plots receiving no treatment produced 33.6 bushels of wheat and 42.1 bushels of barley per acre. Starter fertilizer supplied all the additional nitrogen necessary to produce the highest yield of wheat. An application of 33 pounds N in addition to the starter produced no significant yield increase of wheat, regardless of the carrier or time of application. On the other hand, anhydrous ammonia significantly reduced yields at seeding and in March. Also, solution 41 reduced yields significantly when applied at time of seeding.

The starter fertilizer also increased yields of barley by about 10 bushels per acre over the yields produced by the plots receiving no treatment. Adding 33 pounds N as ammonium sulfate or ammonium nitrate in March increased barley yields 10 bushels per acre. Other nitrogen carriers were significantly inferior in producing yields of barley regardless of time of application.

TABLE 34--EFFECT OF SOURCE AND TIME OF APPLICATION OF NITROGEN ON YIELDS OF WHEAT AND BARLEY ON MEXICO SILT LOAM

Treatments	Yields: Bu./Acre Wheat 7 Yr. Avg.	Yields: Bu./Acre Barley 6 Yr. Avg.
1. No Fertilizer	33.6 d	42.1 h
2. Starter only (10+40+40)	41.9 ab	51.6 f
3. 33 lbs. N as NH_4NO_3 at seeding	43.1 ab	53.3 def
4. 33 lbs. N as Urea at seeding	43.6 ab	53.8 def
5. 33 lbs. N as Anhyd. Ammonia at seeding	38.8 c	49.4 g
6. 33 lbs. N as Soln. 41 at seeding	40.7 bc	53.4 def
7. 33 lbs. N as Soln. 32 at seeding	42.7 ab	52.9 ef
8. 33 lbs. N as $(NH_4)_2SO_4$ at seeding	43.0 ab	54.1 cde
9. 33 lbs. N as NH_4NO_3 in Dec-Jan	43.5 ab	56.3 bc
10. 33 lbs. N as Urea in Dec-Jan	43.7 ab	56.0 bc
11. 33 lbs. N as Soln. 32 in Dec-Jan	42.6 ab	54.7 cde
12. 33 lbs. N as $(NH_4)_2SO_4$ in Dec-Jan	42.4 ab	55.6 bcd
13. 33 lbs. N as NH_4NO_3 in March	42.1 ab	59.8 a
14. 33 lbs. N as Anhyd. NH_3 in March	38.6 c	55.0 cde
15. 33 lbs. N as Soln. 32 in March	43.2 ab	57.5 b
16. 33 lbs. N as $(NH_4)_2SO_4$ in March	43.9 a	60.1 a
$LSD_{.05}$	2.5	2.1

*All plots received starter fertilizer except those receiving no fertilizer at all.

According to this study, nitrogen applications to wheat could be made at almost any time on Mexico Silt Loam by any carrier other than anhydrous ammonia or solution 41. On the other hand, ammonium nitrate or ammonium sulfate applied in March would be the preferred carriers for barley.

CONCLUSIONS
Bradford Research Farm

1. Both wheat and barley responded to phosphorus and potassium in a starter fertilizer even though initial soil test values were relatively high on the experimental sites.
2. The extent of water solubility of phosphorus carriers had no effect on yields of wheat or barley in this study. Advantages of carriers having higher solubility of phosphorus could have been masked by the initially high soil test values of this nutrient.

3. Barley responded to higher nitrogen applications than wheat in this study. In the case of wheat, the 10 pounds N in the starter was sufficient to produce best yields. In barley, an additional 33 pounds N gave significant increase in yields over starter only.
4. Nitrogen can be top dressed on wheat at any time of the year in almost any carrier excepting anhydrous ammonia and solution 41. The preferred nitrogen carriers for barley are ammonium nitrate and ammonium sulfate. March is the best application time.

Part V
North Missouri Center

Some of the land which has become the North Missouri Center was acquired in 1955. Numerous soil fertility studies were begun in 1956 with some yield data being taken in 1957. Among these studies was a comprehensive one on the effects of various quantities of N, P, and K on yield of continuous wheat. Also established was a soil test correlation study involving a four-year rotation of corn-oats-2 years grass and legume mixture. Data from these two experiments are included. The initial soil test values for the experiment sites are given in Table 35.

TABLE 35--INITIAL SOIL TEST VALUES OF EXPERIMENTAL SITES ON EDINA SILT LOAM - NORTH MISSOURI CENTER

	O.M. %	P_2O_5* lbs.	K lbs.	Mg lbs.	Ca lbs.	Salt pH	H** Me	CEC
Soil Test Correlation*	3.2	23	208	590	2900	5.0	5.0	15.1
Continuous Wheat	3.8	69	350	660	6360	5.4	3.2	22.3

*Phosphorus determined by Brays strong extractant.

**Hydrogen determined by old buffer.

RESULTS AND DISCUSSION

Yields of Wheat Grown on Edina Silt Loam

The objectives of this study were to determine effects on yield of wheat grown on Edina Silt Loam, caused by (1) additions of P and K in starters, (2) heavy plow down applications of P and K, and (3) rates of nitrogen. This experiment was established as a non-randomized study with two replications on limed land in 1956. The wheat lodged badly in 1958, and the entire crop was winter killed in 1960. In 1960, a third replication was added, using plots from a study with winter barley which had received the same treatments since 1956. Table 36 includes data obtained since 1960 from the three replications.

Wheat yields on this soil were increased four bushels per acre by use of phosphorus. No yield increase could be attributed to potassium, but yields could be increased three bushels per acre with N in the starter fertilizer. The yield of 40.4 bushels per acre produced by 24 + 24 + 24 starter fertilizer was close to an optimum yield economically. Other treatments increased yields from two to three bushels but they would not have been economical increases. Statistical analyses were not made on this data, but from results of other studies, differences of two or three bushels would be necessary for the differences to be significant.

Even though the initial P level was low, the decomposition of soil organic matter evidently supplied most of the phosphorus needs of wheat under the conditions of this study. The organic matter also supplied enough nitrogen in addition to the 24 pounds in the starter to grow 37.4 bushels per acre. High levels of phosphorus and potassium were ineffective in increasing crop yields.

TABLE 36--EFFECT OF STARTER FERTILIZER, RATES OF NITROGEN, AND HEAVY APPLICATIONS OF PHOSPHORUS AND POTASSIUM ON YIELDS OF WHEAT GROWN ON EDINA SILT LOAM

	Treatments*			
	Starter	Plow Down Applications	Top Dressed Nitrogen	Yield Bu./A 7 Yr. Avg.
1.	None			26.6
2.	24+ 0+24			36.8
3.	24+24+ 0			40.8
4.	0 +24+24			37.5
5.	24+24+24			40.4
6.	24+24+24		33 lbs. seeding	40.1
7.	24+24+24		66 lbs. seeding	40.0
8.	24+24+24		33 lbs. December	40.3
9.	24+24+24		99 lbs. December	38.6
10.	24+24+24		33 lbs. Spring	42.3
11.	None		33 lbs. Spring	34.8
12.	24+24+24		66 lbs. Spring	42.1
13.	24+24+24		100 lbs. Spring	40.2
14.	24+24+24		132 lbs. Spring	38.8
15.	24+24+24	300 lbs. P_2O_5 (20% Super) 60 lbs. K_2O (KCl)	66 lbs. Spring	42.1
16.	24+24+24	300 lbs. P_2O_5 (45% Super) 60 lbs. K_2O (KCl)	66 lbs. Spring	42.1
17.	24+24+24	300 lbs. P_2O_5 (45% Super)	66 lbs. Spring	43.0
18.	24+24+24	300 lbs. P_2O_5 (45% Super) 60 lbs. K_2O (Sulpomag)	66 lbs. Spring	42.9
19.	6 +24+24			40.7
20.	6 +24+24		33 lbs. Spring	43.1

*Superphosphate, muriate of potash and 3 tons limestone were plowed down in 1956. No other plow down treatments have been made since.

Effect of Plant Nutrient Applications on Yields of Spring Oats

The objectives of this study were to determine the response of a corn-oats-grass and legume rotation to various levels of plant nutrients in an Edina Silt Loam soil. As shown in Table 35, the phosphorus and potassium soil test levels were initially low on this experimental site, but the soil organic matter was high. This experiment was established as an unrandomized study with three replications in 1957. The data are reported in Table 37 as averages for the period 1957 to 1966, inclusive.

Using phosphorus in the starter increased oat yields 15.2 bushels per acre over starter containing no phosphorus. Oats in this study did not respond to potassium in the starter fertilizer. Yields were slightly increased by plowing down 200 pounds of P_2O_5 (about 1 bushel per acre) when the carrier was 20 percent superphosphate and about three bushels per acre when the carrier was 45 percent superphosphate. These increases would be of questionable statistical significance. The plans of the experiment originally called for 40 pounds N to be applied to the spring oats, but severe lodging resulted from this application. The nitrogen in the starter proved to be adequate for optimum oat yields.

TABLE 37--EFFECT OF VARIOUS SOIL TREATMENTS ON YIELD OF SPRING OATS GROWN IN A CORN-OATS-2 YEAR GRASS-LEGUME ROTATION ON EDINA SILT LOAM

Treatments			Yield Bu./A
Starter	Plowdown		10 Yr. Avg.
1. 16+0+16			48.2
2. 16+48+16			63.4
3. 16+48+16	200 lbs. P_2O_5 (20% Super)	120 lbs. K_2O (KCl)	64.8
4. 16+48+16	500 lbs. P_2O_5 (20% Super)	120 lbs. K_2O (KCl)	64.9
5. 16+48+16	1100 lbs. P_2O_5 (20% Super)	120 lbs. K_2O (KCl)	64.5
6. 16+48+0	200 lbs. P_2O_5 (20% Super)		64.8
7. 16+48+16	200 lbs. P_2O_5 (20% Super)	240 lbs. K_2O (KCl)	62.5
8. 16+48+16	200 lbs. P_2O_5 (20% Super)	120 lbs. K_2O (K_2SO_4)	66.1
9. 16+48+16	200 lbs. P_2O_5 (45% Super)	120 lbs. K_2O (KCl)	66.4
10. 16+48+16	500 lbs. P_2O_5 (Rock Phos.) (each 8 years)	120 lbs. K_2O (KCl)	63.6
11. 16+48+16	500 lbs. P_2O_5 (Rock Phos.) (in subsoil each 8 years)	120 lbs. K_2O (KCl)	66.2
12. 16+48+16	500 lbs. P_2O_5 (Rock Phos.) (in surface soil each 8 years)	120 lbs. K_2O (KCl)	65.6

6 Tons/A limestone were applied to plots receiving treatments 11 and 12 and 1700 lbs. rock phosphate were applied to plots receiving treatment 11 and plowed 11-12 inches deep in April 1956. The remaining plots received 4T/A limestone in April 1956.

Initial plowdown treatments were applied in 1956.

Soil tests were made on samples taken from plots planted to corn each year and phosphorus added in quantities to bring tests up to 100 lbs. P_2O_5/A on treatments number 3, 6, 7, 9, 10; to 200 lbs. P_2O_5/A on treatment 4; and to 400 lbs. P_2O_5/A on treatment 8.

100 lbs. N as Ammonium Nitrate plowed down each year before corn.

The starter was used on corn and oat crops only.

CONCLUSIONS

North Missouri Center

1. The relatively high level of organic matter in the soil of the wheat experiment released considerable nitrogen so that 24 pounds of N in a starter fertilizer produced optimum yields in this study. Top dressing with additional N either had no effect or decreased wheat yields.
2. Phosphorus in a 24 + 24 + 24 starter increased wheat yields four bushels per acre on soil with a soil test value of 69 pounds of P_2O_5 per acre.
3. Potassium in the starter had no effect on wheat yields with a soil test value of 350 pounds of K per acre.
4. Phosphorus in the 16 + 48 + 16 starter increased spring oat yields by 15 bushels per acre on soil with an initial soil test value of 23 pounds of P_2O_5 per acre.
5. Sixteen pounds N in the starter was adequate for spring oats in this study.
6. Potassium in the starter or as a plow down application had no effect on yields of spring oats where the initial soil test value was 208 pounds of K per acre.
7. 45 percent superphosphate appeared to be a little better than 20 percent superphosphate in the production of spring oats.

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