Table 11. First Year Corn* Morris, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	15.1		
N	60-0-0	13.4	-1.7	-1.47
P	0-40-0	15.5	0.4	0.31
K	0-0-40	17.4	2.3	-1.56
NP	60-40-0	17.4	2.3	2.18
NK	60-0-40	11.7	-3.4	-1.56
PK	0-40-40	13.2	-1.9	-1.88
NPK	60-40-40	12.8	-2.3	
NPK+	100-120-80	15.1	0	

Table 12. Second Year Corn* Morris, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	43.0		
N	80-0-0	34.3	-9.7	-6.9**
P	0-80-0	40.6	-2.4	-1.8
K	0-0-40	41.5	-1.5	-3.0
NP	80-80-0	32.7	-10.3	3.3
NK	80-0-40	29.5	-13.5	1.3
PK	0-80-40	33.5	-9.5	0.2
NPK	80-80-40	34.1	-8.9	
NPK+	120-120-80	37.3	-5.7	

*15.5% Moisture

Table 13. Soybeans Morris, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	15.8		
N	20-0-0	17.8	2.0	0.75
P	0-40-0	18.3	2.5	-0.67
K	0-0-40	17.6	1.8	0.21
NP	20-40-0	14.4	-1.2	0.07
NK	20-0-40	16.9	1.1	1.7*
PK	0-40-40	13.6	-2.2	-0.27
NPK	20-40-40	19.1	3.3	
NPK+	40-80-80	16.3	0.5	

Table 14. Flax Morris, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	15.1		
N	60-0-0	13.6	-1.5	-0.96
P	0-40-0	11.0	-4.1	-2.9**
K	0-0-20	14.5	-0.6	-0.08
NP	60-40-0	11.2	-3.9	0.21
NK	60-0-20	13.6	-1.5	-0.34
PK	0-40-20	12.2	-2.9	0.26
NPK	60-40-20	10.5	-4.6	
NPK+	120-80-40	6.7	-8.4	

Table 15. Alfalfa - Yield of Two Cuttings (15% moisture). Morris, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	1.0		
N	20-0-0	1.2	0.2	-0.42
P	0-80-0	3.2	2.2	1.7**
K	0-0-40	1.1	0.1	0.01
NP	20-80-0	2.4	1.4	-0.52**
NK	20-0-40	1.0	0.0	-0.16
PK	0-80-40	3.4	2.4	0.02
NPK	20-80-40	2.3	1.3	
NPK+	20-160-80	2.6	1.6	

Table 16. Corn - 7 year rotation. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	78.7		
N	40-0-0	70.1	- 8.6	- 3.7
P	0-40-0	94.6	15.9	18.6**
K	0-0-20	66.3	-12.4	- 4.1
NP	40-40-0	90.3	11.6	- 2.9
NK	40-0-20	73.1	- 5.6	2.7
PK	0-40-20	93.4	14.7	0.5
NPK	40-40-20	84.4	5.7	
NPK+	80-120-40	84.6	5.9	

Table 17. Soybeans - 4 year rotation. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	23.8		
N	40-0-0	24.6	0.8	1.6
P	0-40-0	27.5	3.7	3.0*
K	0-0-20	25.8	2.0	-0.1
NP	40-40-0	30.8	7.0	1.0
NK	40-0-20	26.2	2.4	-0.4
PK	0-40-20	26.2	2.4	-1.9
NPK	40-40-20	28.2	4.4	
NPK+	40-120-40	29.7	5.9	

Table 18. Wheat - 4 year rotation. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	24.1		
N	40-0-0	31.2	7.1	13.1**
P	0-40-0	25.5	1.4	8.6**
K	0-0-20	22.3	-1.8	-0.6
NP	40-40-0	46.2	22.1	5.3**
NK	40-0-20	30.8	6.7	-0.9
PK	0-40-20	27.6	3.5	0.4
NPK	40-40-20	43.6	19.5	
NPK+	40-120-40	50.0	25.9	

Table 19. Alfalfa - 4 year rotation. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	0.47		
N	20-0-0	0.52	0.05	0.03
P	0-40-0	0.88	0.41	0.43**
K	0-0-20	0.43	-0.04	-0.05
NP	20-40-0	0.99	0.52	-0.02
NK	20-0-20	0.49	0.02	-0.04
PK	0-40-20	0.91	0.44	-0.02
NPK	20-40-20	0.83	0.36	
NPK+	20-160-80	1.34	0.87	

Table 20. Sugar Beets - 3 year rotation. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	13.8		
N	40-0-0	14.9	1.1	3.02**
P	0-120-0	14.3	0.5	1.12
K	0-0-40	13.9	0.1	1.92*
NP	40-120-0	17.3	3.5	-0.30
NK	40-0-40	19.4	5.6	0.97
PK	0-120-40	16.2	2.4	-0.33
NPK	40-120-40	18.6	4.8	
NPK+	80-240-80	21.7	7.9	

Table 21. Percent Sugar in Sugar Beets. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	% Sugar	Diff.	Treatment effect
None	0-0-0	17.1		
N	40-0-0	14.9	-2.2	-2.18*
P	0-120-0	16.9	-0.2	-0.17
K	0-0-40	17.4	0.3	-0.32
NP	40-120-0	15.2	-1.9	0.35
NK	40-0-40	14.4	-2.7	-0.23
PK	0-120-40	16.5	-0.6	-0.22
NPK	40-120-40	14.6	-2.5	
NPK+	80-240-80	14.2	-2.9	

Table 22. Yield of Sugar. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield Tons/A	Diff.	Treatment effect
None	0-0-0	2.35		
N	40-0-0	2.23	0.12	0.14
P	0-120-0	2.43	0.08	0.15
K	0-0-40	2.41	0.06	0.23
NP	40-120-0	2.62	0.27	0.01
NK	40-0-40	2.80	0.35	0.10
PK	0-120-40	2.62	0.27	-0.09
NPK	40-120-40	2.72	0.37	
NPK+	80-240-80	3.08	0.73	

Table 23. Wheat - 3 year rotation. Crookston, 1959

Treatment	lbs/A $N-P_2O_5-K_2O$	Average Yield bu/A	Diff.	Treatment effect
None	0-0-0	22.1		
N	20-0-0	21.0	-1.1	-1.16
P	0-40-0	30.2	8.1	6.79**
K	0-0-20	25.3	3.2	-0.53
NP	20-40-0	30.6	8.5	1.56
NK	20.0-20	20.9	-1.2	-0.83
PK	0-40-20	27.7	5.6	-2.04
NPK	20-40-20	28.0	5.9	
NPK+	40-80-40	31.4	9.3	

Fertilizer Demonstrations on Sandy Loam Areas of North Central Minnesota

C. J. Overdahl

Fertilizer plots were established on corn and new seedings of alfalfa on sandy loam soils in north central Minnesota in 1959. Plots were established as follows: Corn - Wadena County 4, E. Otter Tail 1, Hubbard 1; alfalfa - E. Otter Tail 1, Wadena 2, Hubbard 1, Todd 2, Crow Wing 1, Milacs 1, and St. Louis 2.

Treatments

Corn - K_2O = 0, 60, 120 and 240#/acre

N = 0, 100, 200#/acre

P_2O_5 = Blanket application of starter phosphate over all plot area.

Alfalfa - K_2O = 0, 60, 120, 240#/acre

N and P_2O_5 = 11-48-0 broadcast at 100#/acre over all plot area.

Gypsum = 0, 100, and 300#/acre

Borated Gypsum = 0, 300#/acre

Results

All but two corn plots failed, apparently due to high temperature and drouth at pollination time. Alfalfa plots will not be harvested until 1960.

No nitrogen response was observed on any plots following alfalfa. No potash response could be observed throughout the growing season.

Henry Pierce Plot - Corn following corn - Wadena County
Soil test: pH 5.5, OM 1.7 (low), P 63 (very high), K 150 med, texture sandy loam.

Average response

K_2O	Yield*	N	Yield**
0	48.2	0	22.4
60	47.5	100	34.7
120	38.0	200	57.3
240	50.2		

* Average of 100# and 200# N levels.
** Average for 4 levels of K_2O.

The increased yields due to nitrogen would appear to be practical even at the 200# rate.

Art Miller Plot - Corn following alfalfa-quack grass sod - Wadena County
Soil test: pH-5.6, OM - 2.4 (low), P-81 (very high), K-100 (med), texture-sandy loam.

		Nitrogen rates			
		0	100	200	Average for K_2O
Rates of K_2O	0	59.5	59.1	64.8	61.1
	60	58.1	56.6	55.4	56.7
	120	59.9	67.5	63.0	63.5
	240	65.8	72.9	64.0	67.6
	Average for N	60.8	64.0	61.8	

There is no apparent nitrogen or definite potash response. The zero potash yields appear high; other than this there is an upward trend with the 60, 120 and 240 lb. potash rates.

Potash furnished by American Potash Institute.
Nitrogen furnished by Tennessee Valley Authority.
Cooperators on plots - Dr. R. D. Munson, American Potash Institute, R. D. Curley, TVA, Miles Rowe, County Agent.

N, P, and K Experiment on Continuous Corn

A. C. Caldwell

This experiment was designed to study the effects of different combinations and rates of N, P, and K on the yield of continuous corn. Twenty-two treatments were laid out in two replicates, of five blocks each, in the spring of 1957.

In 1958 and 1959, no fertilizer was applied in order to study the residual effects of the previously applied fertilizer.

Table 4. The effect of residual N, P, and K on the yield of continuous corn, 1959.

Fertilizer $N-P_2O_5-K_2O$ lbs./A.	Yield bu./A.	diff.
0-0-0	79	---
0-60-37	95	+16
0-60-83	67	-12
37-0-60	72	- 7
37-120-60	69	-10
60-37-0	74	- 5
60-37-120	96	+17
60-60-60	88	+ 9
60-83-0	82	+ 3
60-83-120	82	+ 3
83-0-60	68	-11
83-120-60	91	+12
120-60-37	89	+10
120-60-83	84	+ 5
23-23-23	87	+ 8
23-23-97	84	+ 5
23-97-23	77	- 2
23-97-97	93	+14
97-23-23	77	- 2
97-23-97	103	+24
97-97-23	93	+14
97-97-97	85	+ 6

Overall exp. showed no significance.
Selected treatments of N-P-K at 23 and 97 lbs./A N, P_2O_5, and K_2O showed
K significant @ 10%
NK " @ 5%
PK " @ 5%
LSD (F_{95}) = 13.9

Continuous Corn-High Fertility Experiment
Soils Unit, Rosemount Experiment Station, Rosemount, Minnesota

This experiment was established on a Port Byron silty clay loam at Rosemount in 1953 under the direction of Prof. C. O. Rost. Direction of the project was passed on to W. P. Martin in 1954. Contributions to the project have been made by Prof. Paul Burson and Senior Plot Supervisor H. W. Kramer. Dr. John Grava has run soil tests periodically.

The project is designed to determine profitable rates of fertilization when corn is grown continuously. Rates of application vary from light to heavy and included in the study are different methods of application--broadcast, hill or row

drop with planter attachment, sidedressing with an attachment on the cultivator and combinations of these. Planting rates for corn also vary from approximately 16,000 to 20,000 plants per acre. There are four replications of each treatment.

The site was chosen in a manner which would be compatible with land use recommendations in a conservation farm plan. The site is fairly level so as to minimize erosion, and since it is below a hill-pasture area, it is protected from erosion deposition by terrace structures; it is artificially drained. The soil area has not been heavily cropped in the past and is high in organic matter and "natural" fertility. Randox and 2-4, D are used to help control weeds so as to minimize compaction by cutting down on cultivations, residues are fully incorporated and the principles of minimum tillage are practiced where feasible. Insects are controlled with aldrin.

Corn yields have varied greatly in past years usually because of excess weediness and moisture early and premature frost, severe stalk breakage. In general, however, drought has not been serious and yields have remained high for the area. Check yields have been very good and are not decreasing as rapidly as anticipated. Response to fertilizer has been significant but not as marked as expected largely because of high natural fertility noted above. Results are expected to become more significant with time and it will be of particular interest to note how soon check yields will decline and how long yields can be retained on the fertilized plots at satisfactory levels.

It should be noted also that stalk breakage some years has been quite severe and particularly on the heavier fertilized plots and at the high plant rates.

Fertilizer treatments: (Four replications)

1. Check (no treatment)

	Pounds of Fertilizer Applied		
	6-24-12	10-20-20	33-0-0
	Broadcast	Hill Drop	Sidedress
2.	0	200	0
3.	0	200	100
4.	0	200	200
5.	400	200	0
6.	400	200	100
7.	400	200	200
8.	800	200	0
9.	800	200	100
10.	800	200	200

The plots are approximately 1/25 acre in size and there are six rows in each plot at the 16,000 planting rate and six at the 20,000. Treatments are completely randomized.

Results:

Yields have varied from 45 bushels to 133 bushels (as an average of the treatments) from 1953-1959. Highest yields were obtained in 1954 and lowest in 1957 as a result of excessive precipitation, resulting weediness and premature frost. Yields in 1959 were second highest on record. Response to fertilizer was consistent through all years of the experiment except in 1957 for the reasons above noted.

Yields obtained in 1959 in bushels/acre

	16,000 plants	20,000 plants
1. (Check)	94	109
2. H^*	98	123
3. HS_1	97	121
4. HS_2	105	128
5. B_1H	103	127
6. B_1HS_1	103	131
7. B_1HS_2	102	125
8. B_2H	103	106
9. B_2HS_1	104	128
10. B_2HS_2	110	124
L.S.D.	9.4	10.2

*B_1 =400 lbs. 6-24-12 broadcast
B_2 =800 " " "
H =200 lbs. 10-20-20 hill drop
S_1 =100 lbs. 33-0-0 sidedress
S_2 =200 lbs. 33-0-0 sidedress

Phosphate - Potash Rate and Placement Experiment

Eden Valley - 1958

Lowell Hanson

This experiment was on a Wadena loam soil located near the Crow River in Meeker County. The soil test was: pH - 6.5, P - 15 med., K - 80 low. Corn was the preceding crop and moisture during the growing season was below normal.

Fertilizers used were urea, concentrated superphosphate, and muriate of potash. The broadcast treatments of phosphate and potash were applied before plowing in the spring. Row applied phosphate and potash was placed in a continuous band to the side of the seed with a planter junior applicator. Nitrogen was broadcast when plants were 3 to 4 inches high.

Potassium and nitrogen deficiency symptoms were evident all summer on plots not receiving these nutrients.

Potash treatments significantly increased yields, but phosphate did not. Placement effect was not significant. Phosphate appeared to increase yields at the 20 and 40 lb. rate when no potash was applied.

Ear moisture was 10 to 15 percent higher on plots without potash compared to those receiving some potash.

Corn Yields at 15.5% Moisture

Treatment	Rep I Row	Rep I Broadcast	Rep II Row	Rep II Broadcast	Row Ave.	Broadcast Ave.	Ave.
Check	32		42				37.0
100+0+0	32		43				37.5
100+20+0	45	35	43	67	44.0	51.0	47.5
100+40+0	57	59	59	41	58.0	50.0	54.0
100+100+0	45	29	39	34	42.0	31.5	36.7
Ave.	49.0	41.0	47.0	47.3	48.0	44.2	46.1
100+0+40	72	67	70	72	71.0	69.5	70.2
100+20+40	74	70	68	54	71.0	62.0	66.5
100+40+40	82	63	76	59	79.0	61.0	70.0
100+100+40	62	58	71	59	66.5	58.5	62.5
Ave.	72.5	64.5	71.2	61.0	71.9	62.5	67.3
100+0+80	73	80	90	67	81.5	73.5	77.5
100+20+80	72	68	73	73	72.5	70.5	71.5
100+40+80	66	75	63	68	64.5	71.5	68.0
100+100+80	76	65	74	64	75.0	64.5	69.7
Ave.	71.8	72.0	75.0	68.0	73.4	70.0	71.7
100+0+160	86	80	84	91	85.0	85.5	85.2
100+20+160	76	80			76.0	80.0	78.0
100+40+160	86	76	74	88	80.0	82.0	81.0
100+100+160	76	78	68		72.0	78.0	74.0
Ave.	81.0	78.5	75.3	89.5	78.2	81.4	80.3
Ave. of all plots	66.7	63.5	67.1	67.0	66.9	65.2	

Starter vs. Broadcast Fertilizer Demonstration for Corn in Southwestern Minnesota

C. J. Overdahl

The question frequently arises in the western tier of counties mainly in the Moody-Kranzberg and the Barnes-Aastad areas as to starter fertilizer recommendations. Farmers, fertilizer dealers, and county agents claim that yields are either reduced or are no better than the unfertilized areas.

Locations

Plots were located in the following counties in 1958: Bigstone 3, Stevens 2, Lac Qui Parle 2, Chippewa 2, Yellow Medicine 4, Lyon 3, Pipestone 2, and Rock 2.

The 1959 plots were located as follows: Rock 2, Pipestone 2, Yellow Medicine 2, Lac Qui Parle 1, Chippewa 2, and Swift 2.

Fertilizer Rates

The 1958 plots had 60+0+30 broadcast before plowing over the entire area. Broadcast phosphate was applied at 60 pounds and starter phosphate applied by the farmer averaged 43 pounds per acre. The 1959 plots had two nitrogen rates, 0 and 60 pounds of N as well as a phosphate variable. Phosphate was applied at 40 pounds per acre broadcast and plots averaged 35 pounds for the planter applied starter, although the aim was 40 pounds for both. All plots had 2 replicates.

Weather Conditions

1958 - Subsoil moisture levels were high, but early season rainfall was low. Corn emergence was very uneven due to dry surface soil. On flat, poorly drained soils the surface was wet at planting time. June was very cold.

1959 - Subsoil moisture levels were low. Certain areas had fair rainfall. Temperatures were above normal during tasseling time.

Results (1958) Average increase above check (2 reps)

County	Check	Starter	Broadcast	Broadcast + Starter
Bigstone	67.0	- .2	5.3	8.1
"	35.0	6.4	5.6	16.5
"	33.9	8.1	17.4	23.1
Lyon	74.3	8.5	6.2	9.5
Rock	39.4	6.3	7.6	8.7
Chippewa	59.6	9.4	5.4	18.6
Yellow Medicine	71.3	1.0	13.4	18.2
" "	82.3	10.4	11.2	12.6
Lac Qui Parle	101.4	3.3	8.8	11.9
" " "	90.1	9.3	16.7	27.0
Stevens	66.5	16.6	27.5	30.8
Average	65.5	7.2	11.4	16.8
Value of increase above fertilizer		$2.90	$5.40	$6.50

Several plots were not included in averages because of extreme variability (several bad dried out areas across plots). Plots with no increase beyond check were excluded since difference between starter and broadcast would be unreal.

(1959)

County	N rates	Check	Average increase above check (2 reps) Starter	Broadcast	Broadcast + Starter
Rock	40	54.2	23.6	36.7	51.8
	100	42.0	36.5	34.3	57.0
Rock	0	75.4	4.9	8.2	14.6
	60	85.2	- .5	2.2	8.6
Swift	24	87.6	16.2	8.5	16.9
	84	93.7	- .9	5.1	14.9
Yellow Medicine*	0	51.4	- .2	-12.5	-4.6
	60	47.6	-2.8	-3.9	13.4
Chippewa*	30	44.4	-2.2	7.2	28.8
	90	66.5	-20.5	7.8	6.5
Lac Qui Parle	0	50.2	24.6	6.1	20.6
	60	42.5	25.6	26.2	43.2
Swift*	0	91.5	-3.4	-2.6	-5.8
	60	89.4	- .4	3.6	-3.6
Chippewa*	0	58.8	-2.4	2.0	-2.8
	60	67.5	-12.5	-2.3	-17.3
Average		64.9	7.8	11.4	22.0
Value of increase above fertilizer			$4.60	$7.40	$14.80

*Excluding non response plots $13.00 $11.90

Observations

On poorly drained soils starter fertilizer was very effective. Starter appeared to be less effective than broadcast where surface soil was dry at planting time or if May or June temperatures were too cold for good plant growth. This was the situation for most of the plots in 1958.

The soils in most fields tested relatively low in phosphorus. The combination of starter and plowdown was superior indicating that starter fertilizer was effective if broadcast applications were present for late season needs.

General recommendations for corn based on the above as well as other observations might be as follows:

Where soils are low in phosphorus and high in potassium use a combination of starter and plow-down fertilizer. Starter might be approximately 100 pounds of a 1:4:2 ratio with as near as possible to 1:1:0 ratio plowed down if not following a legume. If following a legume, use straight phosphate as the broadcast material.

If phosphorus levels are in the medium range, use either the starter or broadcast but not both. Little, if any, phosphate response was observed on fields testing high.

Results on Nitrogen

Urea fertilizer* was applied to half of each treatment on the 1959 plots. The following are yield increase averages over no nitrogen treatment from 2 reps where 60 pounds of N were applied. Farmers in many cases applied nitrogen as well, hence in several fields there were no zero nitrogen treatments.

Nitrogen rates		Yield where no N. applied	Phosphate applied as:			
Check	N plot		Check	Starter	Broadcast	Broadcast + starter
**40	100 pounds	44.2	-2.2	10.7	-4.6	3.1
0	60	75.4	9.8	4.4	3.8	3.8
**24	84	87.6	6.1	-11.0	2.7	4.1
0	60	51.4	-3.8	-6.4	5.8	14.2
**30	90	44.4	22.1	3.8	22.7	- .2
0	60	50.2	-7.7	-6.7	12.4	14.9
0	60	91.5	-2.1	0.9	4.1	0.1
0	60	58.8	8.7	-1.4	4.4	-5.8
	Average increase	62.9	3.6	-0.7	6.4	4.3
Average increase over no Nitrogen			1.0	1.8	6.1	5.4

** Plots excluded in average.

All plots either followed corn, soybeans, or oats.

* Supplied by Cyanamid Co.

ROOT DEVELOPMENT AND FERTILIZER PLACEMENT FOR CORN

By

Paul M. Burson and C. O. Rost*

There is an old saying among farmers that if you are going to have good growth above the ground, you are going to have to have good growth below the ground. This is true, but if there is insufficient fertility in the soil, there will be both poor growth of roots and tops. Roots vary in total growth the same as tops. We see large increases in top growth due to the plant nutrients added. We, too, see the root growth vary proportionally. When we see a response to fertilizer, we are definitely sure that the roots, likewise, have increased in growth. The plant nutrients in the soil and the root system that is developed constitute the team that determines the crop yields. The roots pick up the nutrients and water and see that they get to the tops that will produce the crop. When a plant is deficient in nutrients, the top growth shows certain signs of deficiency symptoms. The roots, likewise, change in appearance and growth, but this is not so readily seen because they are hidden in the soil. An example of a root deficiency symptom is the shortage of potash as shown by lodging. In this the roots are restricted in growth, anchorage is weak, so the stalks lodge. Such lodging is characterized by "bow-legged" or curved stalks. Roots are actually the first part of the plant to suffer when a deficiency of nutrients occur.

Root Development

Root response to fertilization has received very little attention and has been studied very little because most attention is given to the yield per acre

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and not what was taking place in the soil where the roots gather the nutrients and water to produce the higher yields. Also, because the roots are in the soil they are hard to see, hard to wash out of the soil so they can be studied. Fertilizer affects roots in some of the following ways:

1. It encourages a more extensive root system.
2. It may encourage a more intensive growth of roots in the zone of fertilizer application.
3. It may change some of the chemical properties of the roots.

Intensive and extensive root growth is essential as follows:

1. Intensive roots more completely utilize the nutrients in the fertilizer band.
2. Extensive roots will penetrate to an area more favorable for minor nutrient availability as in the case of high lime soils of high pH or in highly acid soils of low pH.
3. Better growth and development of roots have larger reservoirs of water to draw on because deeper penetration of the roots, thus giving the plant a larger reserve supply in case of drouth.
4. Corn plants are better anchored to prevent lodging. Winter killing of legumes usually occurs when there is unbalanced or a low supply of essential nutrients, resulting in poorly developed roots.

There are many factors that can influence the extent of the root system such as the type and stage of development of the crop and compaction, aeration, and moisture of the soil. However, in most soils the supply of plant food is the most important single factor limiting root growth. On the other hand, well fertilized soils resulting in good root development may reduce the damage caused by such conditions as compaction and lack of moisture.

In the case of legume roots, if they are to be effective in breaking up a compact layer in the soil, they must be properly fertilized if they are to be vigorous in their growth and deep in their penetration.

More vigorous root growth means better penetration into compacted soils and will reach to greater areas of the soil volume for needed moisture. There is still a lot to be known about why roots expand in well fertilized soils or into a fertilized band.

Plant roots must intercept the fertilizer band in their development and growth. They do not "smell out" the fertilizer and then grow to it. If there is enough plant food, they remain there and proliferate or develop in the band. If there are very small amounts of nutrients, they will continue to grow in all directions. This apparently was the situation a few years ago when the starter rates of fertilizer were low and low analysis fertilizer was used. Corn at knee-high to 18 inches would tend to grow away from the starter fertilizer area. Not too recent experimental work showed this to be true, but now with better placement, higher rates per acre, and much higher concentration of plant food in the fertilizer it may be possible to apply enough fertilizer in the band to feed the crop for the whole season.

The proliferation of the roots in the fertilizer band is in response to the higher nitrogen and phosphate levels. The result is the dividing and elongating of root cells which are in direct contact with the high nitrogen and phosphate concentrations in the fertilizer band. Nutrient uptake and the rate of use by the plant are related to the concentration of nutrients.

Plant physiologists say nitrogen is needed in the roots for protein and enzyme processes. Phosphorus is needed for the metabolic processes. The function of potassium is not exactly known, but it is related to enzyme activity.

All of these nutrients and processes contribute to more growth and root cell division.

For a plant to obtain nutrients and water the roots must be in intimate contact with the soil particles. This is accomplished by the root hairs that develop behind the advancing root tip and by the rapidly dividing cells near the root tip.

Data given in the 1957 U.S.D.A. yearbook, SOIL, on the extensiveness of the root system of a single four-month old rye plant growing in one cubic foot of soil may help to understand soil-root relationships:

	Total Length	Surface Area
Roots	385 miles	2550 sq. ft.
Root hairs	6600 miles	4320 sq. ft.
	6985 miles	6870 sq. ft.

This seems to be a tremendous system of roots, but the surface area of the soil particles in one cubic foot of soil might exceed 500,000 square feet. Therefore, the root system is in contact with only about one per cent of the soil area at any one time. As the roots move through the soil, new root hairs continue to develop and the older ones die. Thus the root system of a plant will come in contact with a considerable proportion of the soil during the life of the plant.

The band of fertilizer occupies a very small volume in the soil. This varies with the kind of fertilizer, rate of application, method of application, and the texture of the soil; but with the average fertilizer on a silt loam soil the effective volume would not exceed an inch square in cross section. Therefore, it may occupy from 1/100 to 1/1000 of the root volume depending on the stage of the growth of the crop. Therefore, such a small volume of ferti-

lizer must be placed where the roots will come in contact with the band. For intensive root development there must be a high concentration of both nitrogen and phosphate. One without the other is of little value and will not result in much root development. The proliferation of roots in the band, of course, will not be as great on soils of high fertility. Under conditions of low soil fertility the basic broadcast application of fertilizers will develop an extensive root system while the band application will develop the more intensive root system. A combination of the two methods will provide a root system that can lead to maximum crop yields providing other practices of good soil management are properly applied.

Fertilizer Placement

Until a few years ago there was little emphasis as to where to place the starter fertilizer as long as it got into the soil - sometimes with the seed, sometimes above it and sometimes directly below it. It didn't seem to matter much because the fertilizer was not concentrated enough to damage germination and the rates per acre were not heavy enough to injure the primary root or sprout, but it did help give the young plant an early start. This placement of fertilizer was made by the old split boot attachment on the corn planter that had been used for many years. Now with present-day fertilizers of higher concentration that are applied at higher rates per acre and at faster speeds the fertilizer comes in contact with the seed resulting in poor germination, reduction of stand, stunted growth, and low crop yields. Where the fertilizer is placed will determine the difference between a good stand, a poor stand, or no stand at all.

The trend today in fertilizer placement for row crops is toward a single band placement which is the safest and most efficient way to place starter fer-

tilizer. The single band attachment on the corn planter can be adjusted so the fertilizer can be placed at a certain distance to the side and below the seed. At the present time the band is usually placed 2 inches to the side and 2 inches below. This placement is safe because the fertilizer salts do not contact the germinating seed sprout (primary roots). It is more efficient because the fertilizer is placed where the feeder roots (secondary or branching roots) can soon intercept the fertilizer nutrients and the band is down where the soil is most likely to be moist. In drier areas it might be well to place the fertilizer 3 inches or more below the seed to take advantage of the deeper soil moisture. At this depth there may be some sacrifice in the quick start in the spring, but if there should be a shortage of moisture later on in the season, this early starter disadvantage might be more than offset by a greater supply of soil moisture.

Plan of Trials

In 1959 starter fertilizer placement trials were conducted with corn on the Soils Farm at Rosemount. The different soil treatments were applied at different rates, placed 2 inches to the side and 2 inches below the seed. The rates of application were 200, 400, and 600 pounds per acre of nitrogen:phosphate ratios of 1:3 (8-24-12), 1:4 (5-20-20), and 3:1 (30-10-0). In the 1:3 and 1:4 ratios, 66 pounds of actual nitrogen were applied as sidedressing in two bands, one on either side of the row in late June. With the 3:1 ratio all the nitrogen for the season was applied in the band as a starter. These trials were conducted on the Port Byron silt loam soil type which was moderately eroded, low in organic matter and nitrogen, and in the fourth year of corn. The soil had been limed at 3 tons per acre. The soil tests showed medium to low levels of available phosphate and potash. Additional phosphate and potash was applied

broadcast as 0-20-20 at 300 and 600 pounds per acre on some of the plots.

The purpose of these trials was to observe what ratios and rates of fertilizers that could be applied in a band as a starter and what would be the difference in root proliferation and yields with the different fertilizer treatments. Different nitrogen:phosphate ratios were used because work in other states seemed to indicate that a 1:3 ratio was the best for root proliferation. This might be true for soils higher in organic matter and nitrogen, but soils such as the ones used in these trials with low organic matter and nitrogen a greater proportion of nitrogen to phosphate might be better.

About August 1 when the roots were fully developed, they were examined to determine if there was any difference in root proliferation and distribution with the different fertilizer treatments. Representative corn root samples from different plots were carefully dug and washed clean to determine how they grew in relation to the fertilizer band, if there was any difference in the extent of proliferation with different fertilizer treatments, methods of application and time of application.

Root Proliferation

Regardless of the fertilizer treatment and method of application all corn roots proliferated in the fertilizer bands.

There was no fertilizer injury to the germination and stand of the corn and growth of the root systems regardless of the rate per acre, grade, ratio of fertilizers used, method, and time of application.

The results show that root proliferation was by far superior with the 3:1 ratio of nitrogen:phosphate than with the 1:3 or 1:4 ratios.

The higher nitrogen in the fertilizer band stimulated the intensive proliferation of the roots.

The most noticeable difference was the tremendous mass of fibrous roots with the 3:1 ratio where all the nitrogen was applied as starter as compared to limited fibrous roots growing in the bands of the 1:3 and 1:4 ratios and where the nitrogen was applied later as sidedressing.

With the 3:1 ratio practically all proliferated roots were concentrated in the single fertilizer band. In the 1:3 and 1:4 ratios with much less proliferation in the fertilizer band there was a similar proliferation of roots in the two bands where the sidedressing of nitrogen was later applied. With this combination of treatments the corn roots were concentrated in three bands while in the 3:1 ratio with all the fertilizer applied as a starter the roots were proliferated in only one band. The question now may be raised as to which distribution of roots would be best in case limited moisture conditions should occur. As far as the total root systems were concerned, there appeared to be no visible difference resulting from the different ratios and the time and method of application provided enough nitrogen was applied.

These observations would indicate that soils low in organic matter and nitrogen are in need of sufficient fertilizer nitrogen along with phosphate and potash if proliferated, vigorous, and intensive root systems are to be developed.

Corn Yield Results

Yields were harvested from all plots (Table I). All fertilizers in 1959 regardless of ratio, rate per acre, methods and time of application gave increases of more than 20.0 bushels per acre over the unfertilized plots. The 0-20-20 fertilizer applied broadcast at 300 and 600 pounds per acre gave yield increases of 21.4 and 25.8 bushels respectively. The root development with this method of application was extensive and well distributed through the top 6 inches of

soil. On all of the other treatments the yield increases in 1959 ranged from 46.1 bushels per acre for treatment 13 to 68.1 bushels for treatment 6. In both treatments the root proliferation was both extensive and intensive because the starter fertilizers were 1:3 and 1:4 nitrogen:phosphate ratios and the additional nitrogen was applied as sidedressing. This resulted in extensive root proliferation developing in three bands instead of intensive root proliferation in one band as was the case in treatments 7, 8, 9, 10, 16, and 17.

In 1958 only limited trials and observations were made. However, similar responses in yield increase and root proliferation were found as in 1959. The yield increases ranged from 17.0 bushels per acre on treatment 20 to 57.0 bushels per acre on treatment 18. The difference of 18.0 bushels per acre in favor of treatment 18 over treatment 19 can probably be contributed to the greater amount of phosphate. The Port Byron soil type is very responsive to phosphate treatments. Further detailed trials need to be made to study root proliferation and corn yields as related to ratio, rates of application, method and time of fertilizer application. The following table gives the details on the yields of different treatments and comparative root proliferation.

Lodging

Considerable lodging occurred on all treatments. The most severe lodging, however, was noted on treatments where no potash was contained in the starter fertilizer.

On treatment 9 there was 23 per cent lodging where phosphate and potash was broadcast in addition to the starter as compared to a high of 52 per cent lodging on treatments 16, when phosphate and potash was broadcast and no potash was included in the starter. Even though potash was added broadcast as 0-20-20 it apparently was not as effective in preventing lodging as if the potash had

been applied in a band as a starter. With intensive root proliferation in the fertilizer band, containing no potash, the roots did not pick up sufficient amounts of the needed potash when it was all applied broadcast.

Table I - Fertilizer Placement, Corn Yield Increases and Root Proliferation

1959

Treatment Number	Fertilizer Treatments	Method Applied	Ratio:[4] Nitrogen to Phosphate	Yield Increase over check Bu./acre	Percent Lodging	Root[5] Proliferation
1	300# 0-20-20	B. C.[1]	-	21.4	-	-
2	600# 0-20-20	B. C.	-	25.8	-	-
3	300# 0-20-20 200# 5-20-20 50# N	B. C. St.[2] S. D.[3]	1:4	49.5	21	E & I
4	600# 0-20-20 200# 5-20-20 50# N	B. C. St. S. D.	1:4	63.6	22	E & I
5	300# 0-20-20 200# 5-20-20 110# N	B. C. St. S. D.	1:4	59.2	24	E & I
6	600# 0-20-20 200# 5-20-20 110# N	B. C. St. S. D.	1:4	68.1	20	E & I
7	300# 0-20-20 200# 30-10-0	B. C. St.	3:1	53.5	34	I
8	600# 0-20-20 200# 30-10-0	B. C. St.	3:1	57.9	36	I

9	300# 0-20-20 400# 30-10-0	B. C. St.	3:1	50.0	23	I
10	600# 0-20-20 400# 30-10-0	B. C. St.	3:1	61.3	39	I
11	200# 5-20-20 50# N	St. S. D.	1:4	51.5	26	E & I
12	200# 5-20-20 110# N	St. S. D.	1:4	52.5	20	E & I
13	200# 8-24-12 60# N	St. S. D.	1:3	46.1	-	E & I
14	400# 8-24-12 60#	St. S. D.	1:3	49.2	-	E & I
15	600# 8-24-12 60# N	St. S. D.	1:3	52.5	-	E & I
16	200# 30-10-0	St.	3:1	51.7	52	I
17	400# 30-100	St.	3:1	53.1	35	I
			1958			
18	400# 8-24-12 60# N	St. S. D.	1:3	57.0	-	E & I
19	400# 8-16-16 60# N	St. S. D.	1:2	39.0	-	E & I
20	200# 8-16-16 60# N	St. S. D.	1:2	17.0	-	E & I

[1] B. C. - Broadcast and disked in or plowed under.
[2] St. - Starter fertilizer applied at time of planting corn.
[3] S. D. - Sidedressed nitrogen applied in late June.
[4] Ratio - Proportion of Nitrogen to phosphate (1:3, 1:4 and 3:1) in the starter fertilizer.
[5] E - Extensive - Root proliferation in starter band and sidedressing bands combination.
I - Intensive - Root proliferation in single band. All fertilizer applied as starter. No sidedressing.

Plant population - 21,000 per acre.
Soil type - Port Byron silt loam.

Progress Report on Fall, Spring, or Sidedressed Nitrate or Ammonium Nitrogen Treatments on Corn in Minnesota.

January, 1960

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Since applications of the two nitrogen fertilizers at the Rosemount field in 1956-57 and in 1957-58 had failed to significantly increase corn yields (due to droughty soil conditions and soil variability in the experimental areas) this location was eliminated from the 1958-59 trials. However, the experiment at the two remaining locations were enlarged to include a June or an early July sidedressing on the Hegne clay at Crookston (in northwestern Minnesota) and on the Barnes loam at Morris (in west central Minnesota). Residual nitrogen effects on crop yield and compaction were studied on each of the three fields.

Since the areas were adjacent to the experimental plots of the two previous years the soil tests were the same:

	Crookston (Hegne clay)		Morris (Barnes loam)		Rosemount (Waukegan silt loam)	
Soil Test	0"-7"	7"-14"	0"-7"	7"-14"	0"-7"	7"-14"
pH	7.6	7.6	7.3	7.4	5.7	5.6
Avail. P (Lbs/A)	15	4	18	8	29	12
Ex. K (Lbs/A)	600+	535	538	458	188	153
% O.M.	5.2	2.1	6.1	4.6	4.8	3.9

Previous cropping history and soil treatments were as follows:

	Crookston	Morris	Rosemount (No 1958-59 experiment)
1954	Oats + 100# of 0-45-0	------	Alfalfa-brome
1955	Durum wheat + 100# of 8-32-0	Soybeans	Corn + 150# of 5-20-20
1956	Durum wheat - no fertilizer	Flax	Flax + 200# of 6-24-12
1957	Oats 125# of 0-47-0 per acre	Corn	Corn + 200# of 8-16-16
1958	Durum wheat - 100# of 0-46-0/A	Silage corn	Corn experiments

The fall nitrogen applications were made at Crookston in late October (soil temperature 45°F) and at Morris on November 8, 1958 (soil temperature 40°F). The nitrogen fertilizers were broadcast and left over winter on the soil surface. Each of the thirteen treatments had six replicates, the individual plot size being 26' 8" x 35' (or 8 x 10.5 rows of 40" spaced corn). The soils were sampled as outlined, but since they were adjacent to the 1957-58 plots, the soil tests were approximately the same. Phosphate-potash fertilizer (500# of 0-20-20 per acre, was broadcast over the entire area at the time of the spring nitrogen treatments at Morris on May 9 (soil temperature 44°), and at Crookston on May 14, 1959 (soil temperature 46°). Soil moisture samples were taken to a depth of six feet with the following moisture percentages obtained:

Crookston - % Soil Moisture - Hegne clay - May 14, 1959

Depth (inches)	Replicate I	II	III	IV	V	VI	Average
0"-12"	17.6	21.1	18.4	21.7	21.6	20.8	20.2
12"-24"	17.3	18.3	19.8	19.6	20.3	19.0	19.1
24"-36"	17.7	18.6	19.6	19.0	20.0	23.2	19.7
36"-48"	18.5	16.4	19.3	21.0	18.6	19.2	18.8
48"-60"	18.9	21.8	19.0	19.1	19.6	23.5	20.3
60"-72"	16.3	21.0	20.7	21.8	29.4	24.0	22.2

Morris - % Soil Moisture - Barnes loam - May 9, 1959

Depth (inches)	Replicate I	II	III	IV	V	VI	Average
0"-12"	14.4	12.9	16.4	13.5	18.7	17.8	15.6
12"-24"	13.8	13.1	14.5	14.1	18.7	18.7	15.5
24"-36"	12.2	9.7	11.9	10.0	14.1	13.9	12.0
36"-48"	14.9	15.8	8.5	11.2	11.2	16.6	13.0
48"-60"	15.7	15.3	10.5	8.5	10.6	14.7	12.6
60"-65"	14.0	15.7	9.3	8.8	13.6	13.3	12.5

The experimental soils at Morris and Crookston were relatively dry when sampled. Soil samples were forwarded in plastic bags to the Iowa soil testing laboratory for analysis.

Plant Populations

The corn was planted in forty inch rows on the two fields, and both were sprayed with Randox for weed control. At Crookston two kernels were dropped at 16" intervals which resulted in a stand of approximately 18,000 stalks per acre. The corn at Morris was thinned to four plants per 40" hill with approximately 15,000 stalks per acre.

Weather

The 1959 growing season was very dry at Morris with drought conditions prevailing in late July and August. The dry soil conditions seriously limited yield and nitrogen effect. Ample rainfall fell at Crookston during July and August, which resulted in good corn yields for this northern area.

Table 1. Monthly Precipitation and Percentage of Normal

Month	Morris		Crookston	
	Total	% of normal	Total	% of normal
October 1958	0.57"	42	2.04"	176
November 1958	1.65"	660	1.95"	212
December 1958	0.16"	25	0.41"	66
January 1959	0.15"	25	0.20"	34
February 1959	0.39"	54	0.37"	63
March 1959	0.12"	10	0.21"	21
April 1959	0.63"	30	0.44"	30
May 1959	5.71"	200	2.48"	95
June 1959	1.65"	42	2.10"	61
July 1959	1.40"	42	3.96"	141
August 1959	3.00"	103	6.13"	196
September 1959	1.20"	63	1.20"	62
Total	16.63"		21.49"	
Deficit	5.25"		Excess 1.23"	

Wheat was grown with no additional fertilizer at Crookston on the 1957-58 fall-spring nitrogen area and oats following wheat on the 1956-57 fall-spring nitrogen area. At Morris, corn was grown on the 1957-58 experimental area and oats were grown on the like area at Rosemount and these yields will be shown later.

1959 Results

Crop yield response from fertilization is still the most important consideration to the farm purchaser and these are shown in the following tables:

Table 2

1959 Yield of Corn and Stover with Fall, Spring, or Summer Applied Nitrate or Ammonium Nitrogen

N (lbs/A)[a]	Application Time	Morris		Crookston	
		Corn - bu/A	Fodder - T/A	Corn - bu/A	Fodder - T/A
None	----	37.2	1.00	71.3	2.25
			Increase above check		
40 NO_3	Fall	7.0	0.10	13.1**	0.45
" "	Spring	2.8	0.11	15.6**	0.41
" "	Summer	8.4	0.01	15.9**	0.56
40 NH_4	Fall	1.4	0.96	4.5	0.04
" "	Spring	8.1	0.00	10.6**	0.21
" "	Summer	0.2	0.00	11.1**	0.40
80 NO_3	Fall	7.3	0.09	18.6**	0.57
" "	Spring	3.3	0.08	18.9**	0.35
" "	Summer	8.0	0.14	20.5**	0.66

80 NH_4	Fall	3.4	-0.17	14.2**	0.15
" "	Spring	14.6**	-0.11	14.2**	0.43
" "	Summer	8.1	0.04	15.6**	0.28

*L.S.D. - (0.05)	9.5 bu.	5.3 bu.
**L.S.D. - (0.01)	12.7 bu.	7.1 bu.
H.S.D. - (0.05)	16.4 bu.	9.3 bu.
H.S.D. - (0.01)	19.1 bu.	10.8 bu.

Means of Grain Yields

40# N	41.8	L.S.D. 1% = 3.9 bu/A	83.2	L.S.D. 1% = 2.8 bu/A
80# N	44.9		88.4	
Diff.	3.1		5.2	
NH_4	43.3	L.S.D. 1% = 3.9 bu/A	83.0	L.S.D. 1% = 2.8 bu/A
NO_3	43.3		88.5	
	0.0		5.5	
Fall	41.9		84.0	
Spring	44.7	H.S.D. 1% = 55 bu/A	86.2	H.S.D. 1% = 3.1 bu/A
Summer	43.4		87.1	

(a) 500 lbs. of 0-20-20 per acre (0-100-100 spring broadcast on all plots.

With the late summer drought, the increased yields of the Morris field are rather questionable. At Crookston, NH_4-Nitrogen seems to be less effective than the NO_3-Nitrogen, especially where the mean values are considered. Time of nitrogen application corn yields varied significantly with the individual treatments, only in the case of the 40 pound NH_4 application, but the summer sidedressing was significantly better than fall fertilization on the means of all plots. On the same basis, the higher rate of N treatment was significantly more effective, especially the nitrate form.

The nitrogen concentrations of the grain and stover are shown in Table 3.

Table 3. Percentage Nitrogen in 1959 Corn Grain and Stover with Fall, Spring, or Summer Applied Nitrate or Ammonium Nitrogen in Minnesota (O. D. basis)

N (lbs/A)	Application Time	Morris Grain	Morris Stover	Crookston Grain	Crookston Stover
		Percentage N			
None	___	1.43	0.62	1.45	0.56
		Increase above check			
40 NO_3	Fall	0.15	0.12	-0.04	0.07
" "	Spring	0.23	0.15	0.11	0.09
" "	Summer	0.18	0.22	0.12	0.22

40 NH_4	Fall	0.11	0.04	-0.22	-0.02
" "	Spring	0.33	0.22	-0.25	-0.07
" "	Summer	0.28	0.33	0.05	0.18
80 NO_3	Fall	0.27	0.30	0.23	0.26
" "	Spring	0.36	0.36	0.23	0.42
" "	Summer	0.34	0.33	0.22	0.32
80 NH_4	Fall	0.23	0.30	0.17	0.21
" "	Spring	0.17	0.50	0.21	0.22
" "	Summer	0.17	0.28	0.14	0.25

Table 4. Pounds of Nitrogen Removed per acre in 1959 Corn Grain and Stover with Fall, Spring or Summer Applied Nitrate or Ammonium Nitrogen in Minnesota.

Applied N (lbs./A)	Application Time	Morris Grain	Morris Stover	Crookston Grain	Crookston Stover
			Pounds N per Acre		
None	----	25.5	12.3	48.9	24.8
			Increase over check		
40 NO_3	Fall	9.0	3.1	7.4	8.5
" "	Spring	4.4	4.5	15.3	9.2
" "	Summer	5.7	4.4	15.9	17.9
40 NH_4	Fall	2.9	0.1	-4.8	-0.7
" "	Spring	12.2	4.0	-2.5	-1.3
" "	Summer	4.8	6.4	11.0	12.5
80 NO_3	Fall	10.3	7.3	22.6	20.8
" "	Spring	6.8	9.1	22.8	24.9
" "	Summer	12.4	9.0	23.6	25.2
80 NH_4	Fall	3.3	3.3	16.6	15.2
" "	Spring	10.2	7.2	18.3	16.3
" "	Summer	8.8	6.1	16.5	15.4

Table 5. Nitrogen Removed per Acre by 1959 Corn Crop and Percentage Recovery of Fertilizer Nitrogen Applied in Fall, Summer, or Spring as Nitrate or Ammonium Nitrogen.

Applied N (lbs/A)	Application Time	Morris		Crookston	
		lbs. N removed	% recovery	lbs. N removed	% recovery
None	----	37.8	----	73.7	----
			Increase over check		
40 NO_3	Fall	12.1	30	15.9	40
" "	Spring	8.9	22	14.6	37
" "	Summer	10.1	25	33.8	85
40 NH_4	Fall	3.0	8	-5.5	-13
" "	Spring	16.2	41	-3.7	- 9
" "	Summer	11.2	28	23.5	59
80 NO_3	Fall	17.6	22	43.4	54
" "	Spring	15.9	20	47.7	60
" "	Summer	21.4	27	48.8	61
80 NH_4	Fall	6.6	8	31.8	40
" "	Spring	17.4	22	34.6	43
" "	Summer	14.9	19	31.9	40

The recovery of nitrogen at Morris was both low and variable. At Crookston a much better recovery was obtained by the summer sidedressing at the lower rate with little difference where 80 pounds of nitrogen was applied. Nitrate nitrogen recovery was higher than with the ammonium form.

Direct and Residual N Fertilization Effect on Crop Yields

In 1959 oats were grown 1957-58 experimental field, and corn was grown as a residual crop at Morris with no additional fertilizer. The yields obtained for the two years are shown in Table 6.

Table 6. Corn Yields at Rosemount and at Morris in 1958 and in 1959 with Nitrate or Ammonium Nitrogen Applied in Fall of 1957 or Spring of 1958.

Applied N (lbs/A)	Application time	Rosemount		Morris	
		1958 Corn	1959 Corn	1958 Corn	1959 Corn
			(bushels per acre)		
Check	----	111.7	82.2	70.5	39.4
			Increase over check		
40 NO_3	Fall 1957	-12.0	1.9	3.5	10.5
" "	Spring 1958	- 3.2	-1.4	-1.0	9.2
40 NH_4	Fall 1957	- 4.5	1.1	-1.8	7.0
" "	Spring 1958	8.8	12.3	2.3	15.5

80 NO_3	Fall 1957	-6.0	-3.3	4.4	14.5
" "	Spring 1958	-8.5	5.1	9.0	9.3
80 NH_4	Fall 1957	-1.4	3.8	6.2	4.0
" "	Spring 1958	-1.5	4.1	2.6	11.1

It is evident that the corn yields in both years were erratic and there was no significant nitrogen effect. Rainfall was somewhat limited in both years at Morris and in 1958 at Rosemount.

Nitrogen effect has generally been more consistent at Crookston then at the other two locations but no residual effect was obtained. The 1956-57 corn yields and that of two succeeding crops are shown in Table 7.

Table 7. The Effect of Nitrate or Ammonium Nitrogen on Yield of Corn and Succeeding Crops at Crookston.

Applied N (lbs/A)	Application Time	Crop yields in bushels per acre		
		1957 Corn	1958 Wheat	1959 Oats
Check	----	44.2	33.9	49.7
		Increases over check		
40 NO_3	Fall 1956	8.3*	-0.4	-3.6
" "	Spring 1957	6.4*	2.0	-4.2
40 NH_4	Fall 1956	3.5	-2.6	0.0
" "	Spring 1957	3.0	-0.1	6.0
80 NO_3	Fall 1956	7.3*	1.6	2.1
" "	Spring 1957	8.0*	1.7	1.7
80 NH_4	Fall 1956	7.2*	-0.1	2.3
" "	Spring 1957	7.5*	3.0	1.0
	*Sig (5%)	6.3 bu.		

Wheat grown at Crookston in 1959 following the 1958 corn experiment showed no residual nitrogen effect and this is shown in Table 8.

Table 8. The Effect of Fall or Spring Applied Ammonium or Nitrate Nitrogen on the Yield of 1958 Corn and 1959 Wheat at Crookston.

Applied N (lbs/A)	Application Time	1958 Corn (bu/A)	1959 Wheat (bu/A)
Check	----	55.6	21.9
		Increase over check	
40 NO_3	Fall 1957	18.3	-0.4
" "	Spring 1958	18.7	1.4
40 NH_4	Fall 1957	13.2	-1.4
" "	Spring 1958	8.4	-1.5
80 NO_3	Fall 1957	24.3	3.8
" "	Spring 1958	22.0	1.2
80 NH_4	Fall 1957	22.3	1.4
" "	Spring 1958	21.1	-0.4

Table 9 presents the pounds per acre of applied fertilizer nitrogen recovered in 1959 wheat (from the 1957-58 N applications for 1958 corn) and in 1959 oats (from the 1956-67 N applications for 1957 corn with wheat grown in 1958). This represents the increased amounts of fertilizer nitrogen found in small grain in the second and third following crops.

Table 9. Pounds of nitrogen present in 1959 wheat grain and straw (following N applications in 1957 and 1958 for corn) and pounds of nitrogen in 1959 oat grain and straw (following N applications in 1956 and 1957 corn and 1958 wheat).

Applied N lbs/A		Pounds of Nitrogen in 1959 Crop					
		Wheat (N applied 1957-58)			Oats (N applied 1956-57		
		Grain	Straw	Total	Grain	Straw	Total
Check		19.1	4.4	23.5	20.5	5.0	25.5
				Increase over check			
40 NO_3	Fall	0.8	0.7	1.5	1.2	0.1	1.3
" "	Spring	2.1	1.4	3.5	-0.9	1.6	0.7
40 NH_4	Fall	-0.9	0.0	-0.9	3.2	-0.4	2.8
" "	Spring	-0.4	1.2	0.8	2.4	1.7	4.1
80 NO_3	Fall	6.1	3.2	9.3	1.0	0.2	1.2
" "	Spring	3.1	1.9	5.0	4.1	-0.7	3.4
80 NH_4	Fall	2.2	0.6	2.8	1.1	0.7	1.8
" "	Spring	1.3	0.6	1.9	-0.2	-0.2	-0.4

Structure - Nitrogen Study
Waseca, 1959
Corn Populations

In 1959 corn was planted at about 22,000 plants per acre so that after population counts it could be thinned uniformly.

There was considerable damage to corn population when corn was 2-3 inches high. Consequently, stands on some plots were very poor.

The damage to population was believed to be due to rodents. Pheasant damage was suspected, paritcularly in minimum tillage plots where birds could hide in the furrow indentations. Two reasons indicated they were not the primary cause of population damage. First, damage boundaries were sharper and more distinct than one normally expects from pheasants. Second, as will be seen later, minimum tillage plots were not consistently damaged even when laying side by side in the field.

Visual observation of the damage indicated whole tillage plots (including in a block all fertilizer treatments) were affected thus that the damage was related to tillage treatment. The following tabulation was made to observe this effect. Values given in the table are plants per 6-row replicate (720 feet of row).

	Tillage Treatment				
Reps	1	2	3	4	5
I	709	454	1143	1136	999
II	911	989	1150	1147	946
III	930	802	1004	1096	897
Totals	2550	2245	3297	3379	2842

Treatments 1, 2 and 5 suffered population damage. Treatments 1 and 2 are spring plowed. Residues in these, and also in 5 to a lesser extent, are left at the surface over winter. Thus rodents may have been either (a) protected from frost or (b) were attracted to spring plowed plots possibly because of food availability.

Part of the observed differences could have been due to differences in germination. This would be suspected from past experience to apply more to treatment 5 than to 1 or 2.

That there were no differences between minimum and conventional tillage is obvious from the tabulated data for treatments 3 and 4. Treatment 4, minimum tillage, fall plowed, had the highest population remaining after rodent damage. There is no evidence that chopping residues affected populati on damage.

In analyzing for yields, moisture content at harvest, and stalk lodging efforts were made to remove the bias of population differences. First, all plots having more than 17,800 plants per acre were thinned to this value. Secondly, rows within plots were selected so as to harvest and count equal populations. Further treatments of the data after yields were taken aimed at eliminating the population bias. These are described in tables where the data are presented.

Structure - Nitrogen Study
Waseca
Corn Yields Bu./A.*
October 10, 1959

Fertilizer Treatment	Tillage Treatment 1	2	3	4	5	Averages
A	112.4	123.1	108.9	99.3	79.6	104.7
B	114.9	131.6	95.3	109.2	88.0	107.8
C	135.6	110.4	103.1	107.2	90.7	109.4
D	117.8	173.4	99.4	112.2	91.1	118.8
E	118.1	121.9	108.8	89.7	85.1	104.7
F	125.5	111.4	90.6	98.5	80.0	101.2
Average	120.7	128.6	101.0	102.7	85.8	

*Yields in above table are from the complete experiment. Where yields from plots with less than 18,000 plants/A. were corrected in proportion to the population deficiency. Since population was poorest on spring plowed land (See separate write-up on corn populations at Waseca; Also data book 16:96), a great proportional correction gives undue favor to spring plowed treatments i.e. 1 and 2. These results are therefore to be interpreted with great caution.

Structure - Nitrogen Study
Waseca
Corn Yields and Moisture*
October 10, 1959

Treatment	Bu./A. 15.5%	Moisture at Harvest
1. Min. tillage, chop residues fall, spring plow	84.8	38.8
2. Min. tillage, not chop, spring plow	92.4	37.8
3. Conv. tillage, chopped, fall plow	88.8	39.0
4. Min. tillage, chopped, fall plow	102.7	37.7
5. Field cultivate fall and spring, chop residues	80.7	39.4
A No fertilizer	89.1	
B 0-40-40	95.9	
C 40-40-40 (fall application)	104.3	
D 40-40-40	98.4	
E 80-40-40	95.0	
F 240-40-40	88.6	

*Values in the above table are from selected plots to avoid those with populations less than about 18,000 per acre. For tillage, values are from 2 reps; for fertilizer, 10 reps. See data book 16:98 for details of selected plots. Since there were 10 fertilizer reps., statistical analysis could be applied; no significant differences were found. See also separate writeup on corn populations.

Structure-Nitrogen Study
Morris
Corn Lodging
1959

Treatment	Lodged Stalks in 70' of row
Tillage	
1. Min. tillage, chop residues, spring plow	15.9
2. Min. tillage, not chop, spring plow	13.8
3. Conv. tillage, chop residues, fall plow	15.1
4. Min. tillage, chop residues, fall plow	18.8
5. Field cultivate fall & spring, shop residues	9.7
L.S.D.	N.S.
Fertilizer	
A. 0-40-40	10.9
B. 40-40-40 (Fall)	13.5
C. 40-40-40	14.9
D. 80-40-40	14.4
E. 240-40-40	19.6
L.S.D.	5.9

Structure-Nitrogen Study
Morris
Percent Phosphorus in 6th Corn Leaf at Tasseling
1959

Treatment	Percent Phosphorus
Tillage	
1. Min. tillage, chop residues, spring plow	.257
2. Min. tillage, not chop., spring plow	.275
3. Conv. tillage, chop residues, fall plow	.248
4. Min. tillage, chop residues, fall plow	.280
5. Field cultivate fall & spring, chop residues	.271
Fertilizer	
A. 0-40-40	.270
B. 40-40-40 (Fall)	.266
C. 40-40-40	.265
D. 80-40-40	.258
E. 240-40-40	.275

Values are averages of 3 replicates. Analysis of variance not made because of several missing plots.

Structure-Nitrogen Study
Morris
Corn Yields Bu./A. at 15.5% H_2O
1959

Treatment	Yield Bu./A.
Tillage	
1. Min. tillage, chop residues, spring plow	43.6
2. Min. tillage, not chop, spring plow	44.4
3. Conv. tillage, chop residues, fall plow	30.1
4. Min. tillage, chop residues, fall plow	40.0
5. Field cultivate fall & spring, chop residues	37.0
Fertilizer	
A. 0-40-40	36.1
B. 40-40-40 (Fall)	40.9
C. 40-40-40	41.5
D. 80-40-40	39.7
E. 240-40-40	36.8

Fertilizer and tillage treatments not significant. A fertilizer tillage interaction was significant at 5% level. The meaning of this is not clear but there is an indication that tillage treatment 5 (unlike other treatments) responded consistently to each added increment of nitrogen. This should be watched in the future.

Structure-Nitrogen Study
Morris
Yield Bu./A*
1959

Treatment	Yield Bu./A.
Tillage	
1, 2. Spring plow	44.0
3, 4. Fall plow	34.8
5. Field cultivate	37.0
L.S.D. (.05)	7.1
Fertilizer	
A. 0-40-40	35.1
B. 40-40-40 (Fall)	40.5
C. 40-40-40	40.2
D. 80-40-40	39.4
E. 240-40-40	37.7
L.S.D. (.10)	3.9

*Fall plowing treatments (3,4) condensed and spring plowing treatments (1,2) condensed so as to test for fall vs. spring plowing.

High Fertility and Wheat Seeding Rates in Clay County

A. C. Caldwell and Merle Halverson

The effect upon corn yield of increasing the plant population when soil fertility and moisture are adequate, is well know. Less attention has been given to comparing small grain yields from various seeding rates when relatively large amounts of fertilizer are used. At ordinary seeding rates, such environmental factors as temperature, light, fertility level and moisture supply are thought to regulate tillering or "stooling" in such a manner that stand becomes adjusted to a more or less optimum level at which existing soil moisture and nutrient supplied are efficiently used.

It was of interest to the Extension Service, the Department of Soils and Deere and Company to determine what the effects of heavy plant population on wheat yields might be, when coupled with conditions of adequate fertility. Last spring these agencies cooperated in putting the idea to preliminary test on the George Landsverk farm in Clay county. The soil was a Bearden silt loam of low phosphorus and high potassium status, on which alfalfa had been plowed down in 1958. Seeding rate totals ranging from 1 to 6 bushels per acre were put down in "criss cross" fashion with a Deere and Company experimental drill. For example, the 5 bushel per acre rate was arrived at by seeding 1½ bushels per acre in a north-south direction and crossing it with a 3½ bushel per acre seeding in an east-west direction. 0-46-0 fertilizer at the rate of 40 lbs. P_2O_5 per acre was placed 1½ inch to the side of, and 1½ inch below the seed in each direction, resulting in a total application of 80 lbs. P_2O_5 per acre. One of the two sets of plots received no nitrogen; on the other, a broadcast nitrogen application of 60 lbs. per acre was made throughout.

No yield differences occurred due to the nitrogen treatment, an observation explainable by the history of alfalfa plowdown on the field the preceding season. Average yields for the 6 seeding rates, calculated to a bushel-per-acre basis, are shown in table 5.

Table 5. Wheat yields at 6 seeding rates with 80 lbs. P_2O_5 placed 1½" x 1½" (Each yield is the average of 4 replicates and 2 nitrogen rates)

SEEDING RATE Bu/A	YIELD Bu/A
1	22.0
2	36.3
3	44.0
4	47.2
5	49.6
6	47.7

Fertilizer Experiment on Continuous Soybeans at Rosemount

A. C. Caldwell and J. Weber

An experiment was set up in 1957 to study the effects of P, K, and barnyard manure on the yields and plant composition of soybeans. Plots were laid out consisting of four replications and fifteen treatments.

In 1958 and 1959 no fertilizer was applied in order to study the residual effects of the previous fertilization.

Yield results for 1959 are included in table 5. Highly significant yield differences resulted on the residual P and K plots. Residual P alone had a significant depressing effect on the yield of soybeans. Plots which had received relatively high rates of both P and K showed a significant increase in yield over those not fertilized.

Table 5. The effect of residual fertilizer on the yield of continuous soybeans, 1959.

Treatment $N-P_2O_5-K_2O$ lbs./A.	Yield bu./A.	Yield diff.
0-0-0	24.3	---
0-0-20	23.2	-1.1
0-0-80	24.4	0.1
0-0-400	26.0	1.7
0-20-20	22.9	-1.4
0-40-40	24.2	-0.1
0-60-60	24.9	0.6
0-80-80	26.3	2.0
0-400-400	28.3	4.0
0-400-400 +6T	27.1	2.8
0-20-0	23.2	-1.1
0-80-0	23.8	-0.5
0-400-0	22.0	-2.3
0-20-0 + 6T	24.2	-0.1
6T	25.8	1.5

LSD (F_{95}) = 2.25

How Great is the Residual or Carry-Over Effect of Fertilizer?

P. M. Burson and C. O. Rost*

The carry-over or residual effect of fertilizers has been observed by many farmers and Experiment Station workers. While farmers have noticed the effect, very few have attempted to measure it accurately.

Many Experiment Station workers, on the other hand, have determined increases produced by the carry-over effect rather accurately.

In this article some of the results obtained by the authors are summarized. Other members of the staff of the Department of Soils, University of Minnesota, have also observed and determined the residual effects of fertilizer.

Under what condition are carry-over effects obtained and what conditions or factors affect them? Just how great an increase in crop yield can be expected and on what crops?

Workers at the University of Wisconsin have estimated the approximate percentages of nitrogen, phosphate, and potash present in the soil and applied in fertilizers and manure, that may be obtained by the first crop grown after the application of the fertilizer. The amounts, as percentages, removed by the first crop are shown in Table 1.

This indicates that only a portion of the available nutrients in the soil, manure, and fertilizer are used by the first crop and that there is a residue left for use by succeeding crops.

There are a number of conditions or factors which will influence the amounts which may be left for the second and succeeding crops. One of these is the rate of application of the fertilizer.

With a light application the amount of nutrients left after the first crop would be less than if heavier applications are used.

A dry season could be a factor, since the growth of the crop might be limited by the amount of moisture and the crop under such condition could not fully utilize the nutrients applied. Likewise such conditions as unseasonable frosts and cold seasons could limit crop growth and nutrient utilization.

In order to obtain a maximum crop yield in normal seasons, the amount of fertilizer applied must be large enough to supply the nutrients which will be used by the first crop, taking into consideration the amounts supplied from the soil and any manure applied to the land.

When this is done there are considerable amounts of nutrients left in the soil which become available to succeeding crops.

Experiments in Minnesota have shown that these subsequent crops are benefited by the unused nutrients. A number of years ago fertilizers were applied for potatoes in the Red River Valley. In the experiments, 45 pounds of P_2O_5 and 120 lbs. of K_2O per acre were applied. The phosphate was applied along the row and the potash broadcasted.

The crop following the potatoes was grain for which no additional fertilizer was applied. The carry-over or residual effect on the grain crops is shown in Table 2.

Table 1. Percentages of nutrients removed by the first crop grown.

Source of Nutrients	Percentages obtained by first crop		
	Nitrogen	Phosphate	Potash
Soil (Available by test).....	40	40	40
Manure (Of total present).....	30	30	30
Fertilizer (Of available).....	60	30	50

Table 2.* Residual Effects of Fertilizers on Grains Following Potatoes

Crop	No. of Fields	Yield on CK Bu/A	Percentage P	Incr. From PK
		HEAVY SOILS		
Wheat	17	28.3	12.2	17.0
Barley	4	41.5	17.0	19.0
Oats	1	72.0	15.2	29.7
		LIGHT SOILS		
Wheat	4	25.4	12.6	24.0
Barley	7	38.8	31.8	51.6
Oats	3	41.8	26.0	24.5

*See Bulletin 385 Minnesota Agricultural Experiment Station.

The carry-over effects in these experiments were considerable, especially on the light textured soils.

It is to be noted that the carry-over effect was greater on barley and oats than on wheat. The effect on the wheat would very probably have been greater if some nitrogen had been included in the fertilizer.

Since yields were determined on only one succeeding crop, these experiments do not show whether or not the effect of the fertilizer might have been evident after the second year.

In another experiment in Nicollet County, fertilizer was applied for a four year rotation of oats-hay-corn-corn. Two hundred pounds per acre of fertilizer was broadcasted for grain and no additional fertilizer or manure applied during the rotation. The soil was a Webster silty clay loam. The percentage increase in yield for the first four crops are shown in Table 3.

The experiment was designed to give the maximum carry-over effect on hay since the main farm enterprise was dairying. The oat crop in which the clover-timothy mixture was seeded was not greatly improved unless nitrogen was included in the fertilizer. Twenty pounds of nitrogen substantially increased yields.

The carry-over on the hay crop was very evident from the percentage increases obtained. While the increases on the two corn crops was less, there is still evidence of some benefit to the crops.

When one considers the total percentage increases for the four crops it is very evident that there is a distinct carry-over effect and it is a worth while one. In the experiment relatively light applications of fertilizer were used and the increase would probably have been greater if a more adequate amount of fertilizer had been used.

The effect of heavier rates of fertilization are shown by an experiment in which the fertilizer was applied for alsike and red clover seed production. The rates used were 500 and 1000 pounds per acre applied for the legume seed crop and no additional fertilizer applied for crops which followed.

Under ordinary circumstances the fields are plowed following the removal of the seed and other crops grown for one or more years and then the land is reseeded to one of the clovers. These experiments were carried out in the northern half of the state since the climate there is favorable for legume seed production.

The results of the experiments are shown in Table 4. It will be noticed the percentage increase in yield on the second crop was generally higher than when ligher applications of fertilizer were used.

The results obtained on field No. 6 deserve special consideration. On this field the fertilizer was applied for alsike clover. Yields were increased from 236 to 352 per cent. Two crops of barley followed and the residual effect was pronounced, especially on the barley which followed the alsike.

In the fourth year the land was in fallow and this was followed by barley. Yields were not determined although very definite effects from the fertilizer were observed.

Alsike clover was seeded with the barley and a crop of seed taken in the following year which was the sixth crop following the application of the fertilizer. Yields of alsike clover seed were still increased from 84 to 162 per cent.

To further demonstrate the long-time residual effect of fertilizers the results of an experiment conducted at the West Central Experiment Station, University of Minnesota, may be cited.

Table 3.* Residual effect of fertilizers on a four year rotation shown as percentage increases over unfertilized land.

Treatment	Rate	1st Crop Oats	2nd Crop Hay	3rd Crop Corn	4th Crop Corn	% Increase Four Crops
0-20-0	200	17.2	33.0	11.1	7.7	69.0
0-20-20	200	4.2	44.8	5.4	4.3	68.7
10-20-0	200	38.5	20.6	2.7	2.5	64.3
10-20-20	200	34.6	27.3	10.9	5.9	78.7

*See Minnesota Agricultural Experiment Station Bulletin 438.