The Effect of Fertilizer Placement on Nutrient Uptake and Yield of Corn under Mulch Tillage

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Many studies (6)[1/] have been made showing the effectiveness of crop-residue mulches in reducing soil and water losses on cultivated land. However, mulch tillage frequently gives lower yields and other evidence of a less desirable growth environment than does conventional tillage. Placement of crop residues on or near the surface has important effects on the physical, nutrient and biological environment within the seedbed. Many investigations have been made of the various factors and relationships involved. Much of the pertinent literature reporting those investigations was reviewed recently by Schaller and Evans (5). They found that in a few studies where adequate fertilizer was applied, corn yields and nutrient content of the plant under mulch tillage were equal to those obtained with conventional plowing but in most experiments yields and nutrient content were lower under mulch tillage. Those results indicate that the depressed yields sometimes obtained with mulch tillage may have been caused by inadeqaute amounts or improper placement of fertilizer.

The purpose of this report is to present results of the fertilizer placement studies at Blacksburg, Virginia, conducted as a part of the mulch tillage research.

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1/ Numbers in parentheses refer to literature cited.

PROCEDURE

Experimental Area. The fertilizer placement tests were conducted in a 20-acre field on the agricultural engineering farm. The soils are of limestone origin, predominately Groseclose silt loam and silty clay loam with small areas of associated Lodi and Greendale silt loams. Slopes range from 3 to 20 percent with moderate sheet erosion. Prior to the establishment of these studies the field had not been intensively farmed for many years.

Cropping Practices. The entire field was contour stripped according to approved specifications at the beginning of the experiment. A conventional 3-year rotation of corn, wheat and clover was used. Corn, being the test crop, received the tillage and fertilizer treatments described in the succeeding paragraphs. The corn was planted for a stand of 13,000 stalks per acre. VPI 645 variety of hybrid seed was used. The wheat and clover crops were grown and harvested according to existing recommendations for those crops.

Tillage Treatment. The double cut plow method of mulch tillage, described in other reports (1, 3, 4), was used as the basic tillage operation. The upper bottom of the double cut plow consists of a standard share and moldboard which inverts the 0 to 3-inch sod layer and a lower bottom without moldboard which simultaneously subtills without turning the 3 to 7-inch layer. The final seedbed was prepared with a spring tooth harrow or similar tool which returns about half of the dead crop residue to the surface. Thus with this method of mulching, all of the residue, including root crowns, of the preceding crops is left either on the surface or distributed within the top 3 inches of soil. In these studies the mulching material was primarily red clover and orchard grass residues.

This method of mulch tillage was compared with the conventional where the sod was turn plowed and the seedbed prepared by discing. Standard tractor mounted planting and cultivating equipment were used with both types of seedbeds.

The terms "DCP" and "TP" will henceforth be used to indicate the double cut plow and the turn plow methods of basic tillage.

Fertilizer Treatments. Fertilizer was applied to the corn at the rate of 100 pounds each of N, P_2O_5 and K_2O per acre, except for one low nitrogen treatment in 1954. The placement variables studied were: all broadcast, broadcast with starter fertilizer banded near the seed row, banding most of nitrogen midway between rows and combinations of these.

A description of the placements tested each year is included in the appropriate tables of results. The part of each treatment applied as starter fertilizer was banded 2 inches to the side and 2 inches below the seed at planting time. The broadcast treatments were applied with a conventional fertilizer spreader immediately preceding preparation of the final seedbed. The nitrogen application between the rows was banded at either 2-inch or 6-inch depths 3 weeks after planting time in 1954 and at planting time in 1955 and 1956.

Plant Analysis. Samples for analysis were taken each year about July 1 when the plants were approximately 24 inches tall and the latter part of September when they were mature. Each sample consisted of two stalks (all growth above ground). They were chopped, dried at 65°C, and ground in a Wiley mill. Total nitrogen was determined by the Kjedahl method. Phosphorus was determined by a modification of the Kitson and Mellon procedure (2). Potassium was determined on a Bechman flame spectrophotometer.

Experimental Design. A split block design was used with a minimum of four replications. Each year the blocks were split one or more times to permit study of related factors, but tillage and fertilizer placement comparisons were always the major consideration.

RESULTS

Rainfall. The April-September monthly rainfall for the 1953-1956 period is given in Table 1 along with the 64-year averages for Blacksburg, Virginia.

Total rainfall during each of the four growing seasons was below the 64-year average. Season deficiencies of 4.95, 6.97, 11.11 and 1.05 inches, respectively, were recorded for the 4 years. The most severe droughts occured during July 1953, June and July 1954, May and July 1955, and May, July and August 1956.

Table 1. April to September rainfall during 1953-56 and the 64-year average for Blacksburg, Virginia.

	April	May	June	July	Aug.	Sept.	Total
1953	2.46	4.17	5.64	2.44	3.16	0.81	18.68
1954	2.07	3.61	1.17	3.98	4.50	1.33	16.66
1955	2.23	1.18	3.72	1.62	3.43	0.34	12.52
1956	3.91	1.96	5.77	3.75	2.86	4.33	22.58
64 Yr. Av.	3.10	4.54	4.26	4.96	3.90	2.87	23.63

1953. The nutrient content of the young and mature corn plants is shown in Table 2 along with the grain yield. The N-P-K contents of the conventional tilled corn were higher than mulch tilled corn at both sampling dates, but these differences were significant (5% level) for the mature plant only.

Table 2. Effects of tillage and fertilizer treatments on the nutrient content and yield of corn - 1953.

Treatment		Grams of N-P-K Per Plant						Grain
		June 26			Mature Plant			Yield
Tillage:	Fertilizer[1]	N	P	K	N	P	K	Bu/Ac
TP	F1	.976	.085	1.526	3.860	.483	3.368	80.5
TP	F2	1.245	.107	1.895	4.343	.523	4.062	86.7
DCP	F1	.887	.073	1.347	3.387	.430	3.040	82.2
DCP	F2	1.129	.094	1.730	4.026	.494	3.367	87.3

1/ Numbers below indicate total lbs. per acre of N, P_2O_5 and K_2O, respectively.

F1 - 100-100-100 broadcast

F2 - 30-30-30 banded as starter plus 70-70-70 broadcast

The fertilizer treatments compared a complete broadcast with part broadcast and part as starter near the seed row. Placement of part of the fertilizer in bands 2 inches to the side and 2 inches below the seed gave significantly greater assimilation of N, P and K for both tillages at each sampling date than did the broadcast application. The lowest values were obtained from the mulch tilled and broadcast treatment (DCP with F1). However, this interaction was not statistically significant.

Yields were slightly higher from mulch tillage. Starter fertilizer (F2) significantly increased (1% level) the yield under both tillages. There were no interactions.

1954. The 1954 experiment included studies of N banded at two depths, 2 and 6 inches, with remainder broadcast or part broadcast and part as starter near seed row. One low nitrogen treatment was included also.

The only differences in plant growth which could be observed during the growing season resulted from the treatment where no starter fertilizer was used. The poorer growth from this treatment was observable on both tillages and persisted until mid-July.

The data on nutrient content of the plant are summarized in Table 3. Grams of N, P and K in the plant on June 29, 1954 are lower than those of the other 3 years. This was due to less growth resulting from low rainfall during June.

At the first sampling on June 29, conventional tillage gave significantly higher (5% level) uptake of N and K than did the mulch tillage. The F4 treatment in which starter fertilizer was omitted gave significantly less uptake of N, P and K. There were no real differences in nutrient uptake between the other fertilizer treatments nor were there interactions between fertilizers and tillage treatments.

The data for the mature plant show several interesting relationships. A significant interaction occured between tillage and fertilizer. Where the fertilizer was broadcast with 70 lbs. N banded at the 2-inch depth midway between the rows (F4), the values for N, P and K contents of the plant were low from the mulch tillage and high from the turn plow. These differences were significant (5% level) for K content and approached significance for N content. The highest uptake of nutrients for mulch tillage was obtained from the treatment receiving 70 lbs. of N at the 6-inch depth (F2). The F3 application, with 70 lbs. of N at the 2-inch depth, gave nutrient uptake only slightly lower than the F2 treatment where the N was banded at the 6-inch depth.

Table 3. Effects of tillage and fertilizer treatments on the nutrient content and yield of corn - 1954.

Treatment		Grams of N-P-K Per Plant						Grain Yield
		June 29			Mature Plant			
Tillage:	Fertilizer[1]	N	P	K	N	P	K	Bu/Ac
TP	F1	.342	.030	.530	3.032	.469	2.754	80.8
TP	F2	.339	.029	.481	3.774	.504	3.088	92.7
TP	F3	.328	.025	.462	3.786	.525	3.095	92.6
TP	F4	.249	.020	.337	3.840	.526	3.211	93.1
DCP	F1	.326	.026	.461	3.095	.492	2.949	82.1
DCP	F2	.330	.029	.489	3.831	.520	3.259	89.8
DCP	F3	.296	.025	.445	3.626	.505	3.002	93.8
DCP	F4	.202	.017	.272	3.348	.479	2.740	85.2

1/ Numbers below indicate total lbs. per acre of N, P_2O_5 and K_2O, respectively.
- F1 - 10-20-20 banded as starter plus 20-80-80 broadcast.
- F2 - 10-20-20 banded as starter plus 20-80-80 broadcast plus 70-0-0 banded midway between rows at 6-inch depth.
- F3 - 10-20-20 banded as starter plus 20-80-80 broadcast plus 70-0-0 banded midway between rows at 2-inch depth.
- F4 - 30-100-100 broadcast plus 70-0-0 banded midway between rows at 2-inch depth.

The grain yields show the same general trends as indicated by nutrient content of the plant. The interaction between tillage treatment and fertilizer placement approached significance. Where starter fertilizer was omitted (F4) mulch tillage produced 8 bu. less than conventional tillage. Under mulch tillage 70 lbs. of N banded at the 2-inch depth with starter fertilizer produced 4 bu. more than the treatment with N banded at the 6-inch depth. Under conventional tillage, yields were about the same at the higher fertilizer rates regardless of placement. Yields were significantly lower from both tillages with the low N treatment.

1955. The 1955 test was limited to a study of the effect of banding most of the nitrogen midway between the rows. The corn was planted during the first week in May under low soil moisture conditions. The freshly prepared seedbed continued to dry rapidly after seeding, resulting in very poor germination on most of the plots. The soil was still dry on May 20 when all the replicates but two were replanted.

N, P and K contents of the corn plant are summarized in Table 4. The plants through the mid-season stage were able to assimilate slightly higher quantities of N, P and K from the F2 treatment which had most of the fertilizer broadcast. This difference can be explained on the basis of the large amount of mineral nitrogen applied in the broadcast treatment relative to the effective root zone of the young plants.

Table 4. Effects of tillage and fertilizer treatment on the nutrient content and yield of corn - 1955.

Treatment		Grams of N-P-K Per Plant						Grain Yield
		July 2			Mature Plant			
Tillage:	Fertilizer 1/	N	P	K	N	P	K	Bu/Ac
TP	F1	.932	.079	1.376	3.481	.412	3.259	78.5
TP	F2	.955	.080	1.480	2.941	.342	3.094	64.1
DCP	F1	.926	.074	1.518	3.479	.369	3.016	79.7
DCP	F2	.962	.084	1.502	2.862	.353	2.823	50.8

1/ Numbers below indicate total lbs. per acre of N, P_2O_5 and K_2O, respectively.
F1 - 20-20-20 banded as starter plus 0-80-80 broadcast plus 80-0-0 banded midway between rows at 6-inch depth.
F2 - 20-20-20 banded as starter plus 80-80-80 broadcast.

In the mature plant, banding 80 lbs. of N at the 6-inch depth between the rows increased the uptake of N, P and K over the application in which most of the N was broadcast. Uptake of N was the same for both types of tillage with this banded application (F1). There was a trend toward less uptake of P and K under mulch tillage with both fertilizer applications. However, the analysis of variance showed none of the differences noted to be significant.

Yields were similar under both tillage treatments with the banded nitrogen application (F1) and averaged 22 bu/ac. more than with the broadcast application (F2). This yield increase was significant (1% level).

Furthermore, there was a significant interaction of tillage and fertilizer placement. Where most of the N was broadcast (F2), mulch tillage produced approximately 13 bu/ac. less than conventional tillage.

1956. Four fertilizer treatments were tested during 1956. These applications were designed to evaluate, under the climatic conditions of a single season, the various types of placements used during the preceding 3 years.

Unusually severe crow damage to the stand during May necessitated replanting on May 30, using the same seed row. Ohio C54, an early maturing hybrid, was used. The new stand from this planting was uniform and of the desired density.

The 1956 plant nutrient contents and grain yields are summarized in table 5. The conventional tilled corn had slightly higher N, P and K contents than that from the mulch tillage plots at the July 10 sampling. The combination placement (F4) gave a significantly greater (1% level) uptake of nutrients than did the complete broadcast (F1). The F2 application, starter near row with remainder broadcast, and the F3 application, 80 lbs. N banded midway between rows with remainder broadcast, were intermediate in uptake of nutrients. The analyses of variance indicated a significant interaction of tillage and fertilizer for P content at the July sampling. This was due mainly

Table 5. Effects of tillage and fertilizer treatments on the nutrient content and yield of corn - 1956.

Treatments		Grams of N-P-K Per Plant						Grain Yield
		July 10			Mature Plant			
Tillage:	Fertilizer[1/]	N	P	K	N	P	K	Bu/Ac
TP	F1	.402	.033	.612	3.539	.523	2.720	70.9
TP	F2	.412	.032	.616	4.011	.572	3.238	79.5
TP	F3	.419	.036	.675	3.941	.558	3.058	82.0
TP	F4	.490	.044	.799	3.731	.562	2.874	80.5
DCP	F1	.339	.027	.534	3.336	.439	2.402	68.9
DCP	F2	.456	.040	.724	3.256	.450	2.435	72.4
DCP	F3	.371	.033	.598	3.516	.498	2.630	73.7
DCP	F4	.455	.038	.801	3.762	.500	2.727	83.9

1/ Numbers below indicate total lbs. per acre of N, P_2P_5 and K_2O, respectively.
F1 - 100-100-100 broadcast.
F2 - 20-20-20 banded as starter plus 80-80-80 broadcast.
F3 - 20-100-100 broadcast plus 80-0-0 banded midway between rows at 6" depth.
F4 - 20-20-20 banded as starter plus 0-80-80 broadcast plus 80-0-0 banded midway between rows at 6" depth.

to the greater response of mulch tillage to the F2 application, which had starter fertilizer placed 2 inches to side and 2 inches below the seed row.

In the mature plant, the conventionally tilled corn assimilated greater quantities of N, P and K than did the mulch tillage. The differences were significant (5% level) for P and K.

Complete broadcast of all the fertilizer gave the lowest uptake of nutrients. Furthermore, there was a significant interaction between tillage and fertilizer. Where the F2 application was used conventional tillage gave the highest uptake of N and K; whereas under mulch tillage the nutrient uptake was about the same as from the complete broadcast. Banding 80 lbs. of N midway between the rows (F3 and F4) increased the uptake of nutrients under mulch tillage. Furthermore, the F4 application, which had starter fertilizer near the seed row and most of the N banded midway between the rows, gave the highest uptake of nutrients under mulch tillage.

The average yield under mulch tillage was 3.5 bu/ac. less than from conventional tillage. This difference was not statistically significant. Yields from the F4 placement were significantly greater (1% level) than from the complete broadcast application under mulch tillage. This type of placement, which combined starter fertilizer near seed row and most of the nitrogen banded midway between the rows, has during the past 3 years consistently produced yields comparable to the highest from conventional tillage. In treatments F2, which included starter fertilizer in the row, and F3, which included 80 lb. of N banded between rows, the yields were intermediate but seven to nine bushels higher with conventional tillage than with mulch tillage.

DISCUSSION

The results from the fertilizer placement studies with mulch tillage show several rather consistent trends. Nutrient uptake and yields were lowest from both tillage procedures where all the fertilizer was broadcast. With other types of placement, where part of the fertilizer was banded as starter near the seed row or most of the nitrogen banded midway between the rows, yields and nutrient uptake were increased. The increases under conventional tillage were about the same from the various banded applications and combinations thereof. However, crop response with mulch tillage was comparable to conventional tillage only when the application included a combination of starter fertilizer near the seed row, most of the nitrogen banded midway between the rows and the remaining P and K broadcast.

The results further confirm previous data which indicate that mulch tillage may affect the environmental relationships in the root zone and thus the nutrition of the plant. More detailed studies are necessary to determine the various factors involved. Nevertheless, the proper placement of fertilizer, as indicated in this paper, appears to overcome the detrimental effects often encountered under mulch tillage. This fact, in view of the recognized effectiveness of crop residue mulches in reducing soil and water losses under cultivated crops, is of considerable practical importance.

SUMMARY

During the period 1953-56 several types of fertilizer placements were studied to determine if placement would overcome the tendency for slight yield depressions which are frequently encountered under mulch tillage. Several combinations of banding and broadcasting the fertilizer were studied. Yields and nutrient content (N, P and K) of the plant were determined. The results of this study indicate that proper placement of fertilizer will overcome the detrimental influence encountered under mulch tillage. Fertilizer application which banded 70 to 80 lbs. of nitrogen between the rows, in combination with starter near the seed row and with the remaining P and K broadcast, consistently gave yields under mulch tillage comparable to the highest obtained from conventional tillage.

Where only starter fertilizer near the seed row or

nitrogen banded between the rows was used and the remaining fertilizer broadcast, yields and nutrient uptake under mulch tillage were lower than from conventional tillage.

Complete broadcasting of the fertilizer gave the lowest crop response with both tillage procedures.

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