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Broadcast Fertilizer Losses in Runoff

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Abstract

No-till is an effective soil conservation practice because it minimally disturbs the soil surface and residue cover. Fertilizer placement in the soil is an extra operation to planting, requiring added weight to the planter and, in

the case of sidedressing, increases surface disturbance. Thus, many farmers resort to surface fertilizer application because it is easier and cheaper to apply. Nutrients in runoff and soil loss from a plot with fertilizer applied by broadcasting were compared to those from a plot where the fertilizer was inserted into the soil at planting and sidedress times.

Concentrations and losses of total P or N in the sediment were little affected by broadcasting fertilizer. Concentrations of NO_3-N, PO_4-P, and NH_4-N in runoff from the broadcast plot were three, three, and six times, respectively, greater than from the inserted-fertilizer plot during the first 29 days after fertilizer application. During the same period, losses of the nutrients in runoff from the broadcast plot were about three, three, and five times greater. Average annual losses of N (all in runoff) attributed to broadcasting were 5.7 lb/a (6.4 kg/ha), 5.2 lb/a (5.8 kg/ha) occurring during the 29-day period after planting. Losses of P in the runoff due to broadcasting were 1.2 lb/a (1.4 kg/ha), 1.0 lb/a (1. 1 kg/ha) in the period after planting. Broadcasting had little effect on nutrients lost during the period between harvest and next-year planting.

Introduction

The no-till system is effective in controlling erosion. However, application of solid fertilizer by a method other than broadcasting requires disturbance of the soil that both increases erosion potential and increases use of energy. Thus, broadcasting fertilizer is an attractive alternative because it is cheaper, easier to apply, and causes less soil disturbance.

Previous research using surface-applied fertilizers has shown more fertilizer nutrients in runoff and sediment than from fertilizer inserted in the soil by tillage. Timmons et al. (1973), using rainfall simulator plots, reported that nutrient losses were inversely related to tillage amount following fertilizer application, i.e., greatest loss from broadcasting, less with fertilizer disked into plowed ground, and least from fertilizer plowed under followed by disking. Also using simulated rainfall, Römkens et al. (1973) measured large concentrations of soluble nitrogen (N) and phosphorus (P) in runoff from coulter and chisel tillage using surface applied fertilizer. McDowell and McGregor (1980) found that solution P concentrations in runoff from no-till on runoff plots were 0.40 mg/L compared to 0.02 mg/L from conventional-till soybeans. Solution plus sediment N and P losses from no-till soybeans were 4.2 and 2.5 lb/a (4.7 and 2.8 kg/ha), respectively. However, no-till greatly reduced soil loss, which in turn reduced nutrient losses to roughly 10 percent of the N and P losses from conventional-till.

McDowell and McGregor (1984) measured N and P losses from corn tillage studies from 1975-1977. Solution N losses (ammonia and nitrate)--were 3.0 lb/a (3.4 kg/ha) from conventional-till corn and about the same, 4.1 lb/a (4.6 kg/ha), from no-till corn. However, losses of N in the sediment were quite different, 30.8 lb/a (34.5 kg/ha) from conventional-till and 6.1 lb/a (6.8 kg/ha) from no-till corn. The large losses in the sediment from conventional-till were credited to its greater (22 times) soil loss. The research reported here is a continuation study of the source of fertilizer nutrients lost in runoff and on soil loss.

The objectives of this research were to determine the concentration, amount, and time of nutrient loss in runoff and soil loss after fertilizer was applied on the surface compared to that lost when fertilizer was inserted under the surface for no-till corn production.

Procedures

Research was initiated in May 1983, at the time of planting corn on two 0.25-acre (0.1-ha) contour plots about 300 feet (100 meters) apart at the North Mississippi Branch Experiment Station, Holly Springs, Mississippi. The plots were designated as N2.5 (north) and S2.5 (south). Runoff data were collected year-round for 3 years. Plots were equipped with 1-ft (0.3-m) H-flumes and FW-1 water level recorders for measuring runoff and Coshocton wheel samplers for sampling suspended sediments. Soil on both plots was Loring silt loam (Typic Fragiudalfs). Slope was 2.5 percent and slope length was 72.6 feet (22 m). Contour rows were 150 feet (46 m) long and maintained on a 0.2 to 0.4 percent slope.

Runoff samples were collected and analyzed for sediment concentration and nutrient concentrations in both runoff and sediment. Measured nutrient concentrations were nitrate-nitrogen (NO_3-N), ammonium-nitrogen (NH_4-N), orthophosphorus (PO_4-P), total sediment nitrogen (TN), and total sediment phosphorus (TP). Analyses were performed using methods described in McDowell and McGregor (1980).

Cultural operations and fertilizer applications are given in Table 1. Corn was planted (drilled) with a no-till planter, which also applied fertilizer under the seed for the insert-fertilizer treatment. Sidedress fertilizer was inserted 10 inches (25 cm) on each side of the corn rows and about 3 inches (7 cm) deep with a chisel-type sod seeder. The same tool was run without fertilizer on the broadcast-fertilizer plot to provide the same soil disturbance on both treatments. The same kind and amount of fertilizer was applied on both plots. Both plots had been used in 1981-82 for a soybean row-width study using conventional tillage. Thus, a buildup of residue typical of that from no-till was not present at the start of the test.

Results and Discussion

This study was not designed to compare yields from the two treatments (Table 1). However, no large differences attributable to the broadcasting treatment were observed, and crop yield was considered as having no effect on nutrients lost in runoff and soil loss. As shown later, the greater amount of broadcast fertilizer in the runoff occurred soon after application when closely followed by rainfall. Therefore, the storm data were accumulated into crop stages defined as follows:

pl/fert - Period beginning with no-till planting and fertilizer application until sidedress fertilizer application.

sd/fert - Period beginning with sidedress fertilizer application until harvesting and stalk shredding.

harv - Period beginning with harvesting and stalk shredding until planting and fertilizer application.

Rainfall, Runoff, and Soil Loss

Rainfall was 52.8 inches (1,341 mm) during the crop year starting with planting corn in 1983 and ending with planting corn in 1984. Rainfall during the 1984-85 and the 1885-86 crop years was 50.0 inches (1,270 mm) and 39.5 inches (1,004 mm), respectively. Long-term (1951 to 1990) average annual rainfall was 54.2 inches (1,376 mm) for the Holly Springs station (McGregor and Mutchler, 1992). Thus, rainfall during the 3-year study was representative of the drier years in Mississippi.

Runoff was sufficient for valid sampling of nutrient losses in the runoff and soil loss. Runoff as a result of rainfall ranged from 6.7 to 9.2 inches/year (170 to 234 mm/yr) on the N2.5 (north) plot and from 5.6 to 11.1 inches/year (142 to 283 mm/yr) for the S2.5 (south) plot. Soil loss amounts also ranged in value with rainfall and plot. Runoff (RO) and soil loss (SL) from the two plots were compared by regressing storm totals to obtain:

$$\mathbf{ROsouth = 1.26 \times ROnorth,\ r^2 = 0.88}$$
$$\mathbf{SLsouth = 1.18 \times SLnorth,\ r^2 = 0.88}$$

The only differences in the two plots, other than inherent variability were method of fertilizer application and soil type. Since broadcasting the fertilizer on the south plot should not affect runoff and soil loss, the approximately 25 percent difference in RO and SL was attributed to plot and runoff measurement differences. Thus, multiplying runoff from each storm on the north plot by 1.25 resulted in an adjusted soil loss and runoff nearly equal to that from the south plot (Table 2).

Solution nutrients from the S2.5 plot were computed by multiplying storm nutrient concentrations by measured storm runoff amounts; adjusted storm runoff amounts were used to compute nutrients from the N2.5 plot. Similarly, sediment nutrients from the S2.5 plot were computed by multiplying storm soil losses by storm sediment nutrient concentrations; adjusted storm soil losses were used to compute losses from the N2.5 plot. The ratio of nutrients lost from the treatments during the harvest to planting crop stage is nearly unity (Figure 2), which is reasonable and supports the adjustment of runoff from the N2.5 plot. Without this adjustment, the difference in runoff and soil loss would cause an underestimate of nutrient loss from the insert-fertilizer plot.

The results of four analyses of variance (ANOVA) are shown in Table 5. Shown together are the results from concentrations of nutrients in runoff, concentration of nutrients carried on the soil loss, loss of nutrients in runoff, and loss of nutrients carried on the eroded soil.

Obviously, the most interesting source of variation is the method of fertilizer application, insert or broadcast. Concentration and loss during the crop stages is of concern because fertilizer applied on the surface would logically be quickly removed by runoff. The time length of the different crop stages must be considered in interpretations of nutrient losses during the year.

The differences between the different nutrients has lesser interest in the ANOVA. Magnitudes of concentration and loss of the different nutrients are the most important concern and are shown in Tables 3 and 4. However, inclusion of the nutrient sources is needed to remove that source of variation for statistical analysis of the data sets.

Years is used almost entirely for replication. Note that the only significant first-order interaction with years is the year-by-crop stage interaction. Although there is some logic to include the first-order interactions that include years, only the second- and third-order interactions were used as error.

Significance of the statistical analysis is discussed in the following sections about nutrient concentrations and losses. Note that adjustment of runoff from the insert-treatment plot had no effect on concentration values. The adjustment only increased losses of nutrients from the insert fertilizer plot, which in turn decreased the difference in losses due to method of fertilizer application. Thus, the ANOVA in Table 5 reflects legitimate differences that would have been greater without the runoff adjustment.

Nutrient Concentrations

The basic measurement of nutrients in runoff and soil loss is concentration. Knowledge of amounts of nutrients leaving farm fields requires the measurement of storm runoff and soil loss with their particular concentrations of nutrients. Unfortunately, concentration from a single sample is often the only measurement available to people interested in pollution, and these concentrations are highly variable. Storm concentrations from the 3-year data set were too voluminous to show in this bulletin; however, the ranges of storm concentration values for each crop stage over 3 years are given in Table 3. Individual storm concentrations contain differences due to variability in time of rainfall after fertilizer application and runoff magnitude, as well as measurement errors. At no time, did the NO_3-N concentration in the runoff from the insert-fertilizer plot exceed the 10 mg/L safe water quality standard (EPA Health Advisory Level for drinking water). Although storm concentrations of NO_3-N were higher from broadcasting, the 10 mg/L level was exceeded because of broadcasting in only one storm (in the pl/fert period) during the 3-year period. More meaningful than the storm values are the concentrations of nutrients in runoff and soil loss weighted by crop stage runoff and soil loss amounts (Table 3). A major result of storm weighting is the reduction of the effect of large variations in concentration often found in runoff from small storms. The weighted data were compared in the analysis of variance (Table 5) that gives a measure of the significance of the obvious differences in nutrient concentrations due to broadcasting fertilizer.

The three measured nutrients (NO_3-N, NH_4-N, and PO_4-P) were carried in the runoff at significantly different average concentrations (Table 5). Runoff-weighted concentrations of NO3-N in the runoff were highest and concentrations of PO_4-P were lowest. Reasons for this ranking are soil-water-chemical interactions and are beyond the scope of this publication. The 3-year average concentrations were 1.21, 0.48, and 0.88 mg/L for NO_3-N, PO_4-P, and NH_4-N, respectively, from the insert-fertilizer plot. The method of application (A) resulted in significantly larger concentrations of nutrients in the runoff. Broadcasting increased average annual concentrations (Table 3) by 1.6, 2.2, and 3.0 times, respectively. This increase is illustrated in Figure 1.

Concentrations were significantly different in the crop stages (C). The interaction of crop stage with nutrients (NxC), application (AxC), and years (YxC) were also significantly different. Most important was the increase in concentration in the pl/fert crop stage when the surface-applied fertilizer was most available to runoff. Increases due to broadcasting in this crop stage were 3, 3, and 60 times for NO_3-N, PO_4-P, and NH_4-N, respectively.

Concentrations of sediment nitrogen (TN) and phosphorus (TP) (Table 5) were not significantly affected by broadcasting fertilizer. Evidently, the broadcast fertilizer did not become attached to the surface of the soil where it would be available for transport by sediment. Also, in contrast to the solution nutrients, the largest concentration of nutrients in the soil loss occurred during the cooler part of the year, from harvest in the fall to planting in the late spring. Concentrations of TN were significantly higher than those of TP. Insert and broadcast annual concentrations of TN were 7,893 and 7,056 mg/kg of sediment, respectively; TP concentrations were 2,258 and 2,082 mg/kg, respectively.

Fertilizer Losses

The amount of fertilizer lost due to broadcasting is important to the economics of farming. Fertilizer losses reduce nutrients available for crop production and may contribute to undesirable off-site effects. Losses of fertilizer nutrients in grams per hectare (g/ha) are given in Table 4. Analyses of variance of nutrient losses in runoff and sediment are given in Table 5. Broadcasting fertilizer did not significantly affect losses of nutrients carried on the soil loss. Average annual loss of TN in the soil loss was 3.6 lb/a (4,041 g/ha); loss of TP was 1.1 lb/a (1,174 g/ha).

Significant differences in annual and crop stage nutrient losses were due to different amounts of runoff from variable amounts and intensities of rainfall. The 3-year average losses reflect the amount of runoff and soil loss in the three crop stages as well as crop stage fertilizer applications. Although the pl/fert period was only about a month long, runoff and soil loss were relatively high in contrast to the sd/fert period, which was about three times longer but with less runoff, and the harv period, which was about 7 months long and included fall and winter. This pattern of runoff was the major cause of the similar amounts of NO_3-N lost in runoff during the three different crop stage periods from the insert plot.

The most important explained differences in soluble nutrient losses are due to broadcasting fertilizer (A) and the application method-crop stage interaction (AxC). Losses of all three nutrients in runoff were significantly higher from the broadcast treatment. The significant application x crop stage interaction indicates that broadcasting causes greater nutrient losses in runoff during the pl/fert and sd/fert crop stages during which fertilizer was applied.

The increase of nutrients lost due to broadcasting is illustrated in Figure 2. The loss of NO_3-N, PO_4-P, and NH4-N in runoff was about three, three, and five times greater from broadcasting in the pl/fert period. The losses were about two times greater during the sd/fert period. The N sidedress didn't increase NO_3-N or NH_4-N losses as much during the sd/fert period compared to pl/fert losses. This is attributed to higher temperatures and less runoff resulting from more canopy and cover during the sd/fert period. Also, use of nutrients by growing corn was greater during this period. Losses of nutrients in runoff from harvest in the fall to planting in the spring were little affected by broadcasting.

Total N lost each year in runoff and sediment from the insert-fertilizer plot averaged 8.4 lb/a (9.4 kg/ha); broadcasting increased this loss to 13.6 lb/a (15.3 kg/ha). Phosphorus loss was 2.1 lb/a (2.4 kg/ha) from the insert- fertilizer plot and 3.4 lb/a (3.8 kg/ha) from broadcasting. These amounts are small compared to the amount of fertilizer applied. Because of the ease of broadcasting and the cost of inserting fertilizer, savings from inserting fertilizer is questionable for no-till. However, when the possible environmental benefits are considered, inserting fertilizer is superior to broadcasting. Note, also, that losses of nutrients increase for farming systems that lose more runoff and soil than no-till. McDowell and McGregor (1984) measured 33.8 lb/a (37.9 kg/ha) of N lost in runoff and sediment from conventionally-tilled corn on standard 5 percent erosion plots.

Summary and Conclusions

Nutrient losses from no-till corn were compared using two 0.25-acre (0.1-ha) contour plots. Fertilizer was inserted with the planter on one plot and broadcasted on the other at planting. Nitrogen was added as a sidedress about 29 days after planting on both plots. The tool used to insert sidedress fertilizer was also used on the broadcast plot to provide the same soil disturbance on both plots, hence the same runoff and soil loss potential.

Measured runoff and soil loss from one plot was about 25 percent less than from the other. This plot variability was removed by adjusting storm runoff values to equalize total runoff and soil loss from both plots so that insert and broadcast fertilizer treatment effects could better be compared. Broadcasting fertilizer had little effect on total N and total P carried on the soil loss. Average of insert and broadcast annual concentration of TN was 7.5 g/kg; TP concentration was 2.2 g/kg. Three-year average annual loss of TN in the soil loss was 3.6 lb/a (4.0 kg/ha); loss of TP was 1.1 lb/a (1.2 kg/ha).

Concentrations of nutrients in runoff were weighted by the runoff in the time period to reduce the large variation in storm values. Average annual concentrations of NO_3-N, PO_4-P, and NH_4-N from the insert-fertilizer plot were 1.2, 0.5, and 0.9 mg/L, respectively. Broadcasting increased the values 1.6, 2.2, and 3.0 times; most of the increase was due to larger concentrations in the pl/fert period. The application of N as sidedress had little effect on nutrient concentrations in runoff and soil loss.

Average annual losses of NO_3-N, PO_4-P, and NH_4-N in the runoff from the insert plot were 2.7, 1.1, and 2.0 lb/a (3.0, 1.2, and 2.2 kg/ha), respectively. Broadcasting increased the annual losses 1.7, 2.3, and 3.0 times as much as from the insert plot. The largest increase was in the 29-day period after planting and fertilizing. Broadcasting increased nutrient losses to a lesser extent during the sd/fert period and had little effect from harvesting to planting.

In summary, broadcasting fertilizer had little effect on nutrients lost in soil loss. The average annual concentration and loss of NO_3-N and NH_4-N, combined, and PO_4-P in runoff, was roughly doubled with broadcasting. Most of the loss of nutrients due to broadcasting occurred in the first 29 days after planting and fertilizer application.

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