CORN PRODUCTION IN NO-TILL AND CONVENTIONAL TILLAGE WITH POULTRY LITTER: A 5-YR DATA

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INTRODUCTION

Corn production in the Southeast is erratic due to intermittent droughts and hot weather during the growing season. Producers must relay upon irrigation for sustained yield. However, low prices along with costs of irrigation made corn production economically risky. Many producers opted to avoid the risk of financial loss by avoiding corn production thus turning the region into one of corn-deficit. Corn production declined from 1.64 million acres in the 1970s to less than 300,000 acres in 2006 in Georgia, for example, with significant declines occurring in the 1980s (Lee, 2007). The newly emerging potential for large-scale renewable bio-energy production has increased the price of corn dramatically as demand for corn-based ethanol, a well-established bio-fuel, is expected to rise sharply supported by the US legislature (Planet Ark, 2005).

Corn producers in the Southeast have potential to compete for this market share but still need to overcome traditional weather and production limitations. Many soils in the Southeast have low water holding capacity and/or root restrictive layers. Crusting is a problem in soils with low organic matter, which encourages runoff from fields. Conventional tillage methods, such as disking and harrowing, encourage development of these adverse soil conditions. No-till systems reduce runoff and soil loss, and increase infiltration as compared to conventional tillage (Bradley, 1995; Endale et al., 2002; Fawcett et al., 1994; Golabi et al., 1995; Radcliffe et al., 1988). No-till systems increase soil water availability, which can partly offset water stress arising due to frequent summer droughts.

Poultry production is a significant source of income for many row crop and cattle producers. In 2005, 8.9 billion broilers were raised in the U.S. with a value of $20.9 billion (NAAS, 2007). Four southeastern states (AL, AR, GA and NC) produced about 50% of these broilers. In the process, almost 14 million tons (2000 lb units) of poultry litter was produced. Poultry litter can be a valuable resource, which provides a wide range of nutrients and organic matter (Moore et al., 1995). It is often an economical alternative to inorganic fertilizers.

Research is required that would quantify yield differentials arising from different choices of tillage and fertilizer sources to help producers make informed decisions. The objective of this research was to quantify the agronomic benefits of no-till and poultry litter in a corn-rye cropping system in comparison to conventional tillage and conventional fertilizer.

MATERIALS AND METHODS

The research was conducted from 2001 to 2005 at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, GA (83^{o}24' W and 33^{o}54' N) on 12 large (30 x 100 ft) nearly level (<2% slope) plots with drainage tiles. The soil is Cecil sandy loam (fine, kaolinitic thermic Typic Kanhapludult). Cecil and closely related soils occupy over half the area of the Southern Piedmont (Langdale et al., 1992). These soils are deep, well drained and moderately permeable. The pH decreases with depth. The soil at the research site has about 8 inches thick Ap-horizon of brown sandy loam, underlain by 2 to 4 inches thick BA-horizon of red sandy clay loam to clay loam texture (Bruce et al., 1983). This is followed by about 40 inches thick red clay Bt-horizon underlain by about 12 inches thick red loam to clay loam BC-horizon. The C-horizon is a loamy saprolite. Total available water in the top 40 inches of soil is approximately 4 inches, not taking changes due to long-term tillage manipulations into account. Long-term average daily air temperature in summer ranges from 75 to 80 ^{o}F at the site. Mean annual rainfall is 48.9 inches. Monthly rainfall distribution varies from 3 inches in October to 5.3 inches in March. The spring rainfall varies 3.7 to 5.3 inches monthly, while that of summer varies 3.8 to 4.8 inches. Short-term summer droughts are frequent in spring and summer with serious consequences on crop yield.

The experiment was laid out as a randomized complete block split plot design with three replications. Conventional tillage (CT) and no-till (NT) were main plots. Fertilizer subplots consisted of ammonium nitrate or sulfate as conventional fertilizer (CF), or poultry litter (PL). The CT consisted of a 12 inches deep chisel plowing followed by one to two diskings to a depth 8 inches and a subsequent disking to 3 inches to smooth the seed bed. The only soil disturbance in NT was a coulter disk for planting. NT treatments have continued on the same plots since the fall of 1991. The combined tillage and fertilizer treatments thus were CT-CF, CT-PL, NT-CF, and NT-PL.

The cropping system consisted of cereal rye (*Secale cereale* L., cv. Hy-Gainer) grown in the late-fall to early spring followed by corn (*Zea Mays*, cv. Pioneer 3223) from mid-spring to mid-fall. Planting and harvest dates consecutively from 2001 were: 05/24 & 10/09; 05/22 & 10/04; 05/29 & 10/22; 04/12 & 09/13; and 05/11 & 10/20. Nitrogen fertilization for corn was at a rate of 150 lbs N acre^{-1} in all but the third year. This meant an application of 5 tons acre^{-1} (30% moisture) for PL. The PL source was from local growers, who usually generate three flocks per cleaning on concrete floors covered with sawdust and shavings. Each flock takes 6-8 weeks to mature. Mineralization of N in PL was assumed to be 50% (Vest et al., 1994) during the corn season. Conventional fertilizer was put out in split applications, one-third a day or two before planting, and two-thirds about 33 days later. The N application rate was doubled to 300 lbs N acre^{-1} in the third year because of interest for detecting potential levels of the hormones estradiol and testosterone coming off the field in runoff or drainage. Amount of these hormones in runoff or drainage had remained at background levels at the application rates of the first two years. The rye cover crop was fertilized with ammonium nitrate at 100 to120 lbs N acre^{-1}. Soil analysis was used to determine P and K needs. All N, P and K fertilizers were applied to the surface of plots one to two days before planting, and incorporated in CT plots only. In addition, a mix of atrazine (1.5 qt acre^{-1}), and dual (1 qt acre^{-1}) was applied before planting and incorporated into soil in CT but not NT plots.

Corn yield was determined by hand harvesting and weighing all whole corn ears from each plot. Twenty to thirty ears were randomly picked from each plot to determine shelled corn weight. The kernel yield was determined in proportion to the whole ear yield of each plot and expressed at 15% moisture equivalent. Statistical analysis was carried out as repeated measures using the MIXED procedure of SAS (Littell et al., 1996; SAS Inst. 1990) with years used as the repeated measure and the experimental blocks used as a random variable. Unless otherwise indicated, all significant differences are given at P = 0.05.

RESULTS AND DISCUSSION

Annual Corn Yield

There were substantial differences in yield between years (Fig. 1; P < 0.0001 for year). Mean yield among years ranked in the order 2002<2003<2001<2004<2005 for CT-CF, CT-PL, and NT-PL. The 2001 and 2004 rankings were reversed for NT-CF. The lowest yields in 2002 varied from 1587 lbs acre^{-1} (28.9 bushels acre^{-1}) for CT-PL to 2342 lbs acre^{-1} (42.6 bushels acre^{-1}) for NT-CF. The highest yields in 2005 varied from 8321 lbs acre^{-1} (151.3 bushels acre^{-1}) for NT-CF to 11934 lbs acre^{-1} (217.0 bushels acre^{-1}) for NT-PL. The average yield over five years varied from 5607 lbs acre^{-1} (102 bushels acre^{-1}) for CT-CF to 7366 lbs acre^{-1} (134 bushels acre^{-1}) for NT-PL.

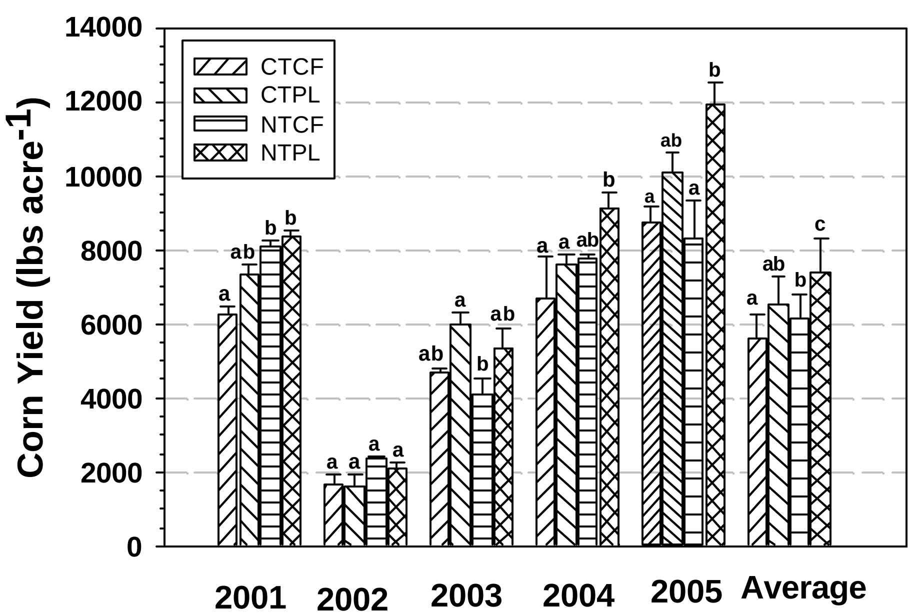

Fig. 1. Corn kernel yield from 2001 to 2005. Within each year, any two treatments sharing similar letters above the error bars are not significantly different from each other at P=0.05.

Several reasons contributed to the yield differential among years, besides treatments, the most prominent of which was variability in precipitation during critical periods (Fig. 2). Conditions for seed germination and early development were particularly unfavorable in 2002 and the plots were irrigated in the amount of 2.2 and 2.6 inches on days 13 and 14, respectively, after planting. The need to induce runoff to monitor hormone levels contributed to the high level of irrigation. Yield was best correlated with total precipitation during weeks 6 to 13 (days 35 to 91 after planting) inclusive. This period closely coincided with the reproductive stages including flowering, pollination, kernel development and grain filling. For the CT the coefficient of determination R^2 was 0.90 with CF and 0.93 with PL. This reduced for NT to 0.61 with CF and 0.77 with PL. Precipitation during this period was 3.9, 9.9, 10.2, 10.3 and 15.5 inches, respectively, in 2002, 2004, 2003, 2001 and 2005. The lowest and highest yields coincided well with the lowest and highest precipitations in all the treatments (Fig. 1). Yield was similar among treatments in 2001 and 2004, which appears to reflect the closeness of the 9.9 and 10.3 inches precipitations of weeks 6 to 13. The yield in 2003 was, however, the second lowest of the five years for about the same precipitation as those of 2001 and 2004. Insect damage was a primary cause of loss of yield in 2003.

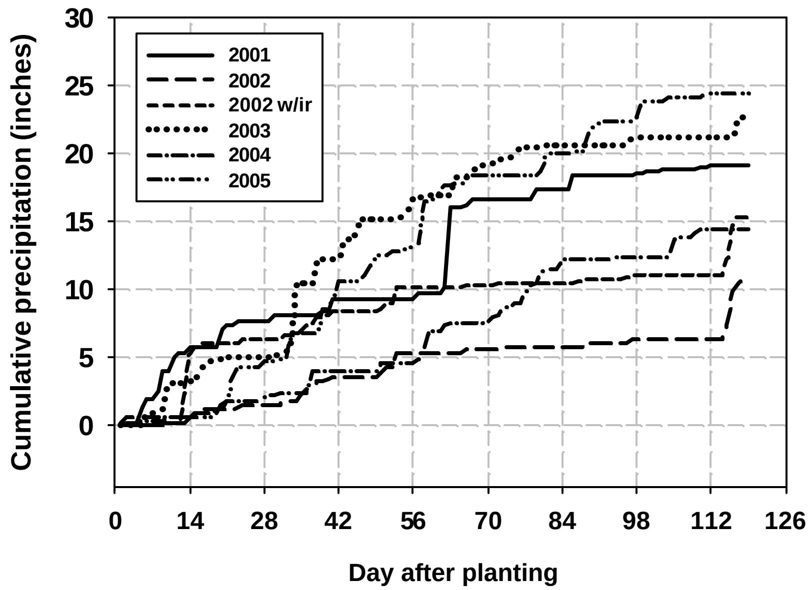

Fig. 2. Cumulative precipitation for the first 120 days during the 2001-2005 corn season

Four of the six NT plots had severe damage to the young shoots in several rows soon after germination, possibly by corn rootworm attack. Replanting became necessary in these rows, which resulted in low yields on these plots. In addition, growth in several NT plots was visibly reduced for a portion of the plot possibly due to insect damage, which resulted in reduced yield. The reasons are not clear, but there was an infestation of corn borer early in 2003 and we sprayed all the plots with Sevin (carbaryl).

In addition to precipitation and insect influences there was likely temperature influences on yield (Fig 3.). In 2002, average weekly maximum temperature was above 90°F and the minimum close to 70°f during the reproductive growth stage. These temperatures were causes of stress in the 2002 corn.

Tillage Effect on Corn Yield

The tillage effect varied from year to year (Fig. 1; P = 0.0319 for tillage; P = 0.0142 for tillage*year; Fig. 1). In CF plots, corn yield with NT significantly exceeded that with CT in 2001 (29%). Yield differences were neither consistent nor significant in the other years. In 2003 NT plots experienced proportionately more insect damage. In PL plots, corn yield with NT significantly exceeded that with CT in 2004 (20.4%). In the other years differences were neither consistent nor significant. Over the five years, average corn yield in NT plots significantly exceeded that in CT plots by 9.2% in plots receiving CF and 13.2% in plots receiving PL. Generally, no-till had greater yield enhancing influence in plots receiving CF in 2001 and 2002 and in plots receiving PL in 2003 to 2005 than corresponding fertilizer treatments.

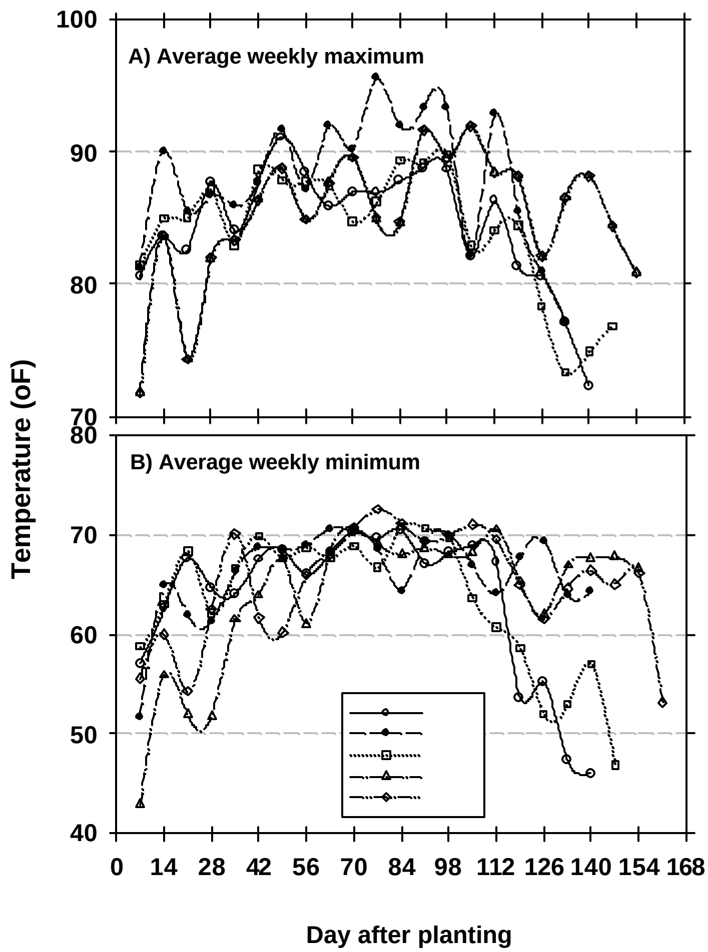

Fig. 3. Average weekly maximum (A) and minimum (B) temperatures during the 2001-2005 corn season

Fertilizer Effect on Corn Yield

The fertilizer effect on corn yield was also variable from year to year (P = 0.0019 for fertilizer; P = 0.0142 for fertilizer*year; Fig. 1). In CT plots those receiving PL had significantly greater yields over 5 years only (16%) despite yearly 15 to 27% differences than those receiving CF. Variability within treatments led to the lack of significance. Results were similar for fertilizer response in NT plots except that differences were significant in 2005 (43%) and over five years (20.3%) (Fig.1). Generally, poultry litter had greater yield enhancing influence in NT than CT plots in 2003-2005.

Combined Tillage and Fertilizer Effect on Corn Yield

The combined no-till and poultry litter treatment effect significantly increased yield by 33 to 36% in 2001, 2004 and 2005, and 31.4% over five years.

CONCLUSIONS

In order for corn growers in the Southeast to maximize benefits from recent increases in corn prices and the bio-fuel based increasing demand, growers need to overcome traditional weather and production related limitations. Together no-till and poultry litter can increase corn production compared to conventional tillage with conventional fertilizer. In conventionally fertilized plots, no-till enhanced yield 9.2% while in plots fertilized with poultry litter it enhanced yield by 13.2% over conventional tillage over five years. Yield pooled across fertilizer treatments was enhanced by 11.4% by no-till. Poultry litter enhanced yield by 16% in conventional tillage plots and by 20.3% in no-till compared to conventional fertilizer over five years. Pooled across the two tillage treatments, poultry litter enhanced yield by 18.2%. No-till and poultry litter combined enhance yield by 31.4% over five years compared to conventionally tilled and fertilized corn. Environmental and management factors can lead to substantial yield variability from year to year across all treatments. Severe water and/or temperature stress and pest pressure can reduce these yield enhancing advantages of no-till and poultry litter. Further research will be needed to determine the threshold of poultry litter application rates that might compromise soil and water quality.

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REFERENCES

Bradley, J.F. 1995. Success with no-till cotton. p. 31-38. *In* M.R. McClelland, T.D. Valco, and F.E. Frans (ed.) Conservation-tillage systems for cotton: A review of research and demonstration results from across the cotton belt. Arkansas Agric. Exp. Stn., Fayetteville, AR.

Bruce, R.R., J.H. Dane, V.L. Quisenberry, N.L. Powell, and A.W. Thomas. 1983. Physical characterization of soils in the southern region: Cecil. Southern Coop. Series Bull. No. 267. University of Georgia, Athens, GA.

Endale, D.M., D.E. Radcliffe, J.L. Steiner, and M.L. Cabrera. 2002. Drainage characteristics of a Southern Piedmont soil following six years of conventionally tilled or no-till cropping systems. Transactions of the ASAE: 45(5): 1423-1432.

Fawcett, R.S., B.R. Christensen, and D.P. Tierney. 1994. The impact of conservation tillage on pesticide runoff into surface water: A review and analysis. J. Soil and Water Cons. 49(2):126-135.

Golabi, M.H., D.E. Radcliffe, W.L. Hargrove, and E.W.Tollner. 1995. Macropore effects in conventional-till and no-tillage soils. J. Soil and Water Cons. 50 (2):205-210.

Langdale, G.W., L.T. West, R.R. Bruce, W.P. Miller, and A.W. Thomas. 1992. Restoration of eroded soil with conservation tillage. Soil Technology. 5(1): 81-90.

Lee D. A guide to corn production in Georgia 2007. 2007. Lee D. (ed). The University of Georgia College of Agriculture and Environmental Sciences, Cooperative Extension Service, Crop and Soil Science Department, Athens, GA.

Littell, R. C., G.A. Milliken, W.W. Stroup, and W.R. Wolfinger. 1996. SAS Systems for Mixed Models. SAS Inst., Inc. Cary, NC.

Moore Jr., P.A., T.C. Daniel, A.N. Sharpley, and C.W. Wood. 1995. Poultry manure management: Environmentally sound options. J. Soil and Water Cons. 50(3): 321-327.

NASS. 2007. Poultry – Production and Value 2006 Summary. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture.

Planet Ark. 2005. World Environment News. FACTBOX – Biofules take off in some countries. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm Accessed 5-8-2007.

Radcliffe, D.E., E.W. Tollner, W.L. Hargrove, R.L. Clark, and M.H. Golabi. 1988. Effect of tillage practices on infiltration and soil strength of a Typic Hapludult soil after ten years. Soil Sci. Soc. Am. J. 52 (3):798-804.

SAS Institute, Inc. 1990. SAS/STAT User's Guide, Ver. 6. 4th ed. SAS Institute Inc. Cary, NC:

Vest, L., B. Merka, and W.I. Segars. 1994. Poultry waste: Georgia's 50 million dollar forgotten crop. Leaflet 206/July, 1994. Georgia Cooperative Extension Service, College of Agricultural and Environmental Sciences, University of Georgia. Athens, GA. At http://www.ces.uga.edu/pubcd/L206-w.html. Verified 27 Dec. 2003.