INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
11–469/AWB/2012/14–1–29–37
http://www.fspublishers.org

Full Length Article

Nitrogen Uptake Pattern by Cotton in a Long-term No-tillage System with Poultry Litter Application

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ABSTRACT

Nitrogen uptake pattern by cotton (*Gossypium hirsutum* L.) at different growth stages in response to long-term application of poultry litter (PL) in a no-till system (NT) was studied on a silt loam soil in 2009. The study was done in plots that were established in 1996 at TVREC, Belle Mina, AL, USA. Treatments included were three tillage [conventional tillage (CT), mulch-tillage (MT), and no-tillage (NT)], two cropping systems [cotton-rye (C-R; cotton in summer & cereal rye cover crop in winter), and cotton-fallow (C-F; cotton in summer & fallow in winter)], and two sources of nitrogen [PL at 100 and 200 kg N ha^{-1} and ammonium nitrate (AN) at 100 kg N ha^{-1}]. Out of all treatment combinations only 11 important treatments were selected and arranged in a randomized complete block design and replicated 4 times. Results in 2009, showed that NT system can supply equal quantity of nitrogen compared to CT at all growth stages. No-tillage recorded similar growth, yield and total nitrogen uptake compared to CT. Application of PL at 100 kg N ha^{-1} showed significantly superior plant growth compared to AN at early growth stage, but the differences disappeared as the plant growth progressed. Similar yields and nitrogen uptake were observed with application of either PL or AN at 100 kg N ha^{-1}. Application of a double rate of PL (200 kg N ha^{-1}) resulted in significantly higher nitrogen uptake compared to that of PL or AN at 100 kg N ha^{-1}, but a significant yield advantage was not observed with this higher rate. Of the total nitrogen extracted by cotton at maturity, 50% uptake was completed by early flowering stage and 97% was completed by boll development stage. At maturity, the majority of nitrogen (52%) was partitioned into seeds, while the rest was distributed into leaves (16%), stems (18%) and reproductive parts (14%). winter rye cover crop did not influence nitrogen uptake.

Key Words: Conventional tillage; Cover crop; Mulch tillage; Nitrogen uptake; No-tillage; Poultry litter

INTRODUCTION

Traditional intensive agricultural practices deteriorate soil health (Nyakatawa *et al.*, 2001a; Triplett & Dick, 2008). A wide range of sustainable agricultural practices improve soil quality. For example reducing tillage, increasing organic content in the soil by adding local available organic wastes and crop residues, crop rotations, and ensuring sufficient ground cover to protect soil from erosion during off season etc. No-tillage (NT) is the most adapted conservation tillage system which involves planting seeds in a narrow slot opened by the planter with minimal disturbance of the surface residue. The long term benefits of conservation tillage are reduced soil loss through erosion (Nyakatawa *et al.*, 2001a), decreased cost of inputs (Duiker, 2004) and improved soil physical, chemical and biological properties (Six *et al.*, 2002; Grandy *et al.*, 2006; Teasdale *et al.,* 2007). In addition, NT also helps in sequestering CO_2 from the air, which in turn helps to slow global warming (Lal, 2004; Roberson *et al.*, 2008).

Cotton is a major crop grown in southeastern USA. Out of total upland cotton area of 10.9 million acres in the USA, 30% of the crop is grown in southeastern states (Arkansas, Mississippi, Alabama, Georgia, South Carolina & North Carolina) (USDA-National Agricultural Statistics Service, 2010a). Significant benefit and loss in cotton yields in response to NT have been reported (Nyakatawa *et al.,* 2000; Raper *et al.*, 2000; Schwab *et al.*, 2002; Reddy *et al.,* 2009). Previous studies have reported that no-till cotton production can be made more sustainable by including a winter cover crop (Schwenke *et al.,* 2001; Boquet *et al.,* 2004; Reddy *et al.*, 2004). Cover crops add crop residues which help in retaining more soil water, building up the soil organic matter, and preventing soil erosion (Nyakatawa *et al.,* 2001a). Cover crops also have the ability to prevent groundwater contamination by nitrate leaching by acting as scavengers on carry over nutrients from the previous crop (Staver & Brinsfield, 1998; Dabney *et al.*, 2001).

Utilizing local available organic wastes such as poultry litter, cattle manure, sewage sludge, and industrial by-

To cite this paper: Reddy, S.S., E.Z. Nyakatawa and K.C. Reddy, 2012. Nitrogen uptake pattern by cotton in a long-term no-tillage system with poultry litter application. *Int. J. Agric. Biol.*, 14: 29–37

products etc., as nutrient sources for crops can help in safe disposal of those organic wastes. Out of 8.63 billion broilers raised in the country, Southeastern states i.e., Georgia, Arkansas, Alabama, Mississippi, North Carolina and South Carolina accounts for 60% of the production (USDA-National Agricultural Statistics Service, 2010b). Poultry industry in above states generates approximately 8 billion kg of poultry litter [(manure+bedding material) (PL)] every year (1.5 kg litter/bird) and raises concerns for its safe disposal. Poultry litter can be used as a fertilizer for crop production and it helps in dispose of this byproduct in economical and environmentally beneficial way. Many investigations proved that poultry litter has salutary effects on crop production and soil quality (Mitchell *et al.*, 1995; Miller, 1996; Reddy *et al.,* 2009).

Investigations revealed that combination of conservation tillage, poultry litter application and cover crops will improve soil quality and give sustainable cotton yields (Nyakatawa *et al.*, 2001b; Reddy *et al.*, 2007). There is big difference between conventional and no-tillage systems in method of fertilizer application. In conventional tillage, the nutrient source gets mixed up with soil, whereas in no-tillage it is surface applied. Consequently, there may be difference in mineralization and subsequent nutrient release patterns between these two tillage systems. Efforts were made to study nitrogen extraction pattern by cotton in response to poultry litter application (Tewolde *et al.*, 2007). However, combined and long-run effects of no-tillage, poultry litter and cover crops on nitrogen extraction pattern by cotton are poorly documented. Increased understanding of nitrogen extraction pattern by cotton throughout the season may help to improve nitrogen use efficiency and to avoid excess nitrogen application. The main aim of this experiment was to study the nitrogen extraction pattern by cotton in a long-term no-till system with poultry litter application and a winter cover crop.

MATERIALS AND METHODS

Experimental location, treatment details and design: In 1996, a long term field experiment was initiated at the Tennessee Valley Research and Extension Center, Belle Mina, Alabama, USA (34° 41' N, 86° 52'W). Soil type is Decatur silt loam (clayey, kaolinitic thermic, Typic Paleudults). Eleven treatments consisting were evaluated in this study (Table I). The treatments consisted of combination of three tillages: conventional-till (CT), mulch-till (MT), and no-till (NT); two cropping systems with and without cover crop: cotton in summer and cereal rye cover crop in winter (C-R) and cotton in summer and fallow in winter (C-F); and two nitrogen sources and rates: ammonium nitrate at 100 kg N ha^{-1} and poultry litter at 100 and 200 kg N ha^{-1}. Because of limitations on land availability only 11 important treatments were selected from all treatment combinations and were laid out in a randomized complete block design with four replications.

Quantity of poultry litter (PL) to be applied was calculated based on the nitrogen content of it. Prior to land application, total N concentration of PL was determined by LECO 2000 carbon and nitrogen analyzer (LECO Corporation, St. Joseph, MI, USA). On average, the PL used in the study contained nitrogen at 30 g kg^{-1}. The amount of nitrogen available from PL to the crop during first year would be around 60% of total applied N (Keeling *et al.*, 1995), hence PL application rates were calculated by considering only 60% of total N. On the day of planting, prior to tillage operations, total quantity of PL and AN were hand applied to the plots. Ammonium nitrate was applied at a rate of 100 kg N ha^{-1}, which is recommended dose for cotton in the region (Adams *et al.*, 1994). In CT and MT plots PL was applied at 100 kg N ha^{-1}, but two rates (100 & 200 kg N ha^{-1}) were used in NT treatments to see if higher rates of PL could safely be disposed of. Since NT has become the standard practice for cotton production in the region, litter treatment at higher rate (200 kg N ha^{-1}) was included only in the NT system (Table I).

Tillage operations were carried out after PL and AN application. Conventional tillage was done by moldboard plow and chisel plow in November and April, respectively to a depth of 15 cm. After chiseling, before cotton seeding, a disk plow was drawn to a depth of 10-15 cm. Moldboard plowing and disking were absent in mulch-tillage, but only chisel plowing was done. In CT and MT plots a roterra was used to level the soil and prepare fine seed beds. In NT plots soil was not disturbed except opening furrows for seeding purpose. PL and AN were incorporated into soil in CT and MT plots due to tillage operations, while in NT plots the fertilizers were left unincorporated on the top of the soil.

Following tillage operations, cotton was planted at 16 kg ha^{-1} seeding rate at a spacing of 1-m between rows. Plot size was 8 m x 9 m. Irrigation was applied as and when required. In 2009, 80 mm of irrigation water was applied during the experiment. All other operations such as pest control and cotton defoliation were done as per the local recommendations.

As a rotation, every third year corn was planted after two continuous years of cotton. The history of cropping pattern followed in this long-term experiment from 1997-2009 is explained in Table II. Corn was planted in all plots uniformly at 75,000 plants ha^{-1} without applying any tillage or fertilizer treatments. Every year after cotton harvest, the cover crop winter rye was planted in fall season with a no-till drill at a seeding rate of 60 kg ha^{-1} in selected plots according to the treatment plan (Table I). No fertilizer was applied to the cover crop. In the spring, about 7 days after flowering, rye cover crop was killed by spraying glyphosate [*N*-(phosphonomethyl) glycine] herbicide at 1.12 kg a.i. ha^{-1}. Each year at least 4 weeks of time gap was maintained from killing of winter rye to next cotton planting to allow maximum drying of residues. Winter rye was skipped in corn planting years, because corn is a crop that generally adds enough crop residues to protect the soil (Table II). Row spacing maintained for corn and rye were 1 m and 20 cm, respectively.

Data collection: In 2009, cotton growth components, plant height, and dry matter accumulation in above ground plant parts were measured four times at 30, 61 (early flowering stage), 97 (boll development stage) and 137 (maturity stage) days after planting (DAP) and nitrogen concentration in plant parts were measured three times at 61, 97 and 137 DAP. These measurements were taken from four plants selected from center two rows of each plot. The plants were cut at ground level and separated into leaves (petioles+leaf blade), stems (main stem+branches) and reproductive parts (flowers+squares+bolls). Plant height was measured on main stem from ground level to tip of the terminal bud. All plant parts were dried at 80°C to a constant weight and ground to pass through a 1-mm sieve. At 137 DAS, after drying, matured bolls were further separated into burs, lint and seed. Remaining flowers, immature bolls, and burs were mixed up and ground to pass 1-mm sieve. Lint was separated from seeds using cotton gin and seeds were de-linted by immersing them in concentrated H_2SO_4 before grinding. Plant samples were analyzed for total nitrogen using the C/N analyzer (LECO CN2000, LECO Corporation, St. Joseph, MI). Lint samples were not analyzed for nitrogen content as the nitrogen concentration in lint was reported to be very low at maturity (Fritschi *et al.,* 2004; Tewolde *et al.,* 2007). The amount of N accumulated in each plant part was calculated by multiplying N concentration with dry weight of that part. Total N uptake by each plant was calculated by summing N accumulated in all parts. At maturity, seed cotton yields were determined by picking them twice in the center four rows of each plot.

Data analysis: Growth, nitrogen concentration in plant parts, total nitrogen uptake and seed cotton yields were analyzed using the general linear model procedures of the Statistical Analysis System (SAS Institute, 2004). Since the treatments were arranged in an incomplete factorial design (Table I), only treatments 2, 3, 4 and 8 were used to find the interaction effect of tillage x cropping system because they have uniform tillage and cropping system combinations. Similarly, to find the effect of tillage x N source interaction, treatments 4-9 were used. Using the LSD procedure, treatment means were compared at alpha level 0.05.

RESULTS AND DISCUSSION

Weather data: Fig. 1 explains the monthly rainfall and temperature records at experimental site during the crop season in 2009. Crop had received excess rainfall in all months compared to 30 years average (1980-2009) except in the month of June. Totally 1289 mm of rainfall was received during the crop season in 2009 against the 30 years average of 851 mm.

Growth: Cotton plant height was significantly influenced by N sources at all growth stages but was not influenced by tillage and cropping systems (Table III). Application of nitrogen through AN or PL significantly increased plant height at all stages compared to the control (0 kg N ha^{-1}). At early stages of growth (30 DAP), application of PL at 100kg N ha^{-1} recorded significantly higher plant height (20.08 cm) compared to that of AN at the same rate (15.61 cm). This is attributed to the readily available inorganic fraction of nitrogen present in PL. These differences in plant height

Table I: List of treatments used in the long-term study, Belle Mina, Alabama

Treatment	Tillage	Cropping System		Nitrogen Source	Nitrogen rate (kg/ha)
		Summer	Winter		
1	Conventional-till	Cotton	Rye	None	0
2	Conventional-till	Cotton	Fallow	Ammonium Nitrate	100
3	No-till	Cotton	Fallow	Ammonium Nitrate	100
4	Conventional-till	Cotton	Rye	Ammonium Nitrate	100
5	Conventional-till	Cotton	Rye	Poultry Litter	100
6	Mulch-till	Cotton	Rye	Ammonium Nitrate	100
7	Mulch-till	Cotton	Rye	Poultry Litter	100
8	No-till	Cotton	Rye	Ammonium Nitrate	100
9	No-till	Cotton	Rye	Poultry Litter	100
10	No-till	Cotton	Fallow	None	0
11	No-till	Cotton	Rye	Poultry Litter	200

Table II: Cropping scheme followed during 1996-2009, Belle Mina, Alabama

Season	Year	Cropping System
Summer	1996	Cotton
Winter/Spring	1996/1997	Rye
Summer	1997	Cotton
Winter/Spring	1997/1998	Rye
Summer	1998	Cotton
Winter/Spring	1998/1999	Fallow
Summer	1999	Corn
Winter/Spring	1999/2000	Rye
Summer	2000	Cotton
Winter/Spring	2000/2001	Rye
Summer	2001	Cotton
Winter/Spring	2001/2002	Fallow
Summer	2002	Corn
Winter/Spring	2002/2003	Rye
Summer	2003	Cotton
Winter/spring	2003/2004	Rye
Summer	2004	Cotton
Winter/spring	2004/2005	Fallow
Summer	2005	Corn
Winter/spring	2005/2006	Rye
Summer	2006	Cotton
Winter/spring	2006/2007	Rye
Summer	2007	Cotton
Winter/spring	2007/2008	Fallow
Summer	2008	Corn
Winter/spring	2008/2009	Rye
Summer	2009	Cotton

Table III: Plant height, dry matter accumulation in leaves and stems at different growth stages as influenced by tillages, nitrogen sources and cropping systems, Belle Mina, Alabama, 2009

	Plant height (cm)				Leaf weight (g/plant)				Stem weight (g/plant)			
	30DAP	61DAP	97DAP	137DAP	30DAP	60DAP	97DAP	137DAP	30DAP	60DAP	97DAP	137DAP
Tillage (T)												
CT†	17.06	81	115	112	0.87	14.07	22.61	9.29	0.34	12.93	34.94	27.31
MT	17.25	81	112	113	0.80	15.52	23.44	12.22	0.31	15.33	32.38	31.22
NT	17.54	82	113	115	0.85	13.46	22.37	8.87	0.34	12.92	34.39	30.24
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N Source (NS)												
0N	14.96 B††	63 C	73 C	77 C	0.51 C	8.23 B	12.64 C	3.21 B	0.19 C	6.92 B	17.25 C	12.65 C
100ANN	15.61 B	79 B	117 A	116 AB	0.75 B	13.76 A	23.70 B	8.54 A	0.26 B	12.39 A	35.13 B	29.87 AB
100PLN	20.08 A	86 AB	108 AB	110 B	1.01 A	14.94 A	20.96 B	11.97 A	0.44 A	15.41 A	32.38 B	28.57 B
200PLN	20.42 A	90 A	121 A	124 A	0.95 A	14.66 A	27.94 A	12.00 A	0.44 A	15.30 A	43.58 A	36.72 A
P > F (0.05)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cropping System (CS)												
C-F	15.54	80	117	114	0.81	13.68	23.49	7.94	0.29	12.33	36.00	28.17
C-R	17.87	82	112	113	0.86	14.38	22.41	10.48	0.35	13.92	33.43	29.86
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions												
T X CS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T X NS	0.0038	NS	NS	NS	0.0021	NS	NS	NS	0.0002	NS	NS	NS

Table IV: Influence of tillage, nitrogen source and cropping system on reproductive parts, seed, lint and total plant weight at different growth stages and seed cotton yield at maturity, Belle Mina, Alabama, 2009

	Reproductive parts weight (g/plant)		Seed weight (g/plant)	Lint weight (g/plant)	Total plant weight (g)				Seed cotton (kg/ha)
	97DAS	137DAP	137DAP	137DAP	30DAP	61DAP	97DAP	137DAP	
Tillage (T)									
CT†	31.56	14.23	19.50	14.22	1.21	27.00	89	85	3582
MT	30.25	15.94	21.26	16.38	1.11	30.85	86	97	3540
NT	30.23	15.16	22.01	16.72	1.19	26.38	87	93	3729
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N Source (NS)									
0N	19.39 C††	7.37 C	11.37 B	8.68 B	0.69 C	15.16 B	49 C	43 C	2303 B
100ANN	29.80 B	15.29AB	20.99 A	15.55 A	1.01 B	26.16 A	89 B	90 B	3720 A
100PLN	32.32 B	14.50 B	20.82 A	16.05 A	1.45 A	30.35 A	86 B	92 AB	3486 A
200PLN	45.13 A	18.61 A	25.50 A	18.59 A	1.39 A	29.97 A	116 A	111 A	3878 A
P > F (0.05)	<0.0001	<0.0001	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cropping System (CS)									
C-F	31.17	14.47	20.27	14.98	1.10	26.00	91	86	3729
C-R	30.55	15.20	21.18	16.02	1.20	28.31	86	93	3595
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions									
T X CS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T X NS	NS	NS	NS	NS	0.0009	NS	NS	NS	NS

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter, 200PLN= 200 kg N ha^{-1} as poultry litter, C-F = cotton (summer) followed by fallow (winter), C-R= cotton (summer) followed by rye (winter)
††Treatment means followed by the same upper case letter are not significantly different from each other at $P \leq 0.05$

between AN and PL at 100 kg N ha^{-1} disappeared at later stages of growth. Application of PL at a double rate (200 kg N ha^{-1}) recorded similar or higher plant height compared to that of AN and PL at 100 kg N ha^{-1}. Cotton plant height was also significantly influenced by tillage and N source interactions only at early growth stage (30 DAP) (Table III & Fig. 2). In all three types of tillage application of PL at 100 kg N ha^{-1} resulted in significantly higher plant height compared to AN at the same rate. Rapid growth in plant height was observed between 30 and 61 days after planting. As plant growth progressed, differences in plant height due to tillage and N source disappeared in later stages. At 61, 97 and 137 DAP, all tillage systems showed similar plant heights either with AN or PL at 100kg N ha^{-1}. These results indicate that PL was a better nitrogen supplier than AN for the first few weeks after application and it supplied equal amount of nitrogen compared with AN at later stages. Application of a double rate of PL (200 kg N ha^{-1}) in no-till system did not significantly influence the plant height compared to that of PL at 100kg N ha^{-1} at all stages. Winter rye cover also crop did not influence plant height at all growth stages (Table III).

Similar results were also observed in other growth parameters such as dry matter accumulation in leaves, stems, reproductive parts, seeds and lint, and overall plant weight at maturity. Application of PL at 100 kg N ha^{-1} resulted in significantly higher leaf, stem and total plant weight compared to that of AN at the same rate at 30 DAP

Table V: Nitrogen concentration in plant parts at different growth stages as influenced by tillage, nitrogen sources and cropping systems, Belle Mina, Alabama, 2009

	Leaf N (g/kg)			Stem N (g/kg)			Reproductive parts N (g/kg)	Seed N (g/kg)
	61DAP	97DAP	137DAP	61DAP	97DAP	137DAP	137DAP	137DAP
Tillage (T)								
CT†	39.65	28.80	26.15	18.36	8.08	9.69	15.63	37.55
MT	36.74	28.49	24.62	15.96	7.67	9.69	15.00	39.61
NT	39.02	29.25	24.18	17.85	8.72	9.98	15.36	41.43
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
N Source (NS)								
0N	32.65 B††	20.76 C	22.04 B	14.70 B	7.38	9.40	11.37 B	40.98
100ANN	40.65 A	30.80 A	25.83 A	19.51 A	8.35	9.71	16.45 AB	39.19
100PLN	35.38 AB	25.62 B	23.53 AB	14.27 B	8.07	9.98	13.50 A	40.33
200PLN	37.41 AB	29.92 A	26.52 A	16.74 AB	8.03	10.17	16.45 A	40.14
P > F (0.05)	0.0095	<0.0001	0.01	0.0012	NS	NS	0.0012	NS
Cropping System (CS)								
C-F	40.24	31.12	25.81	18.75	8.48	9.55	16.99	38.54
C-R	38.17	28.09	24.69	17.18	8.16	9.91	14.77	40.00
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interactions								
T X CS	NS	NS	NS	NS	NS	NS	NS	NS
T X NS	0.0035	0.033	NS	NS	NS	NS	NS	NS

Table VI: Nitrogen accumulation in plant parts at different growth stages as influenced by tillage, nitrogen sources and cropping systems, Belle Mina, Alabama, 2009

	Leaf N (g/plant)			Stem N (g/plant)			Reproductive parts N (g/plant)		Seed N (g/plant)	Total N uptake (kg/ha)		
	61DAP	97DAP	137DAP	61DAP	97DAP	137DAP	97DAS	137DAP	137DAP	61DAP	97DAP	137DAP
Tillage (T)												
CT	0.57	0.66	0.24	0.24	0.29	0.26	0.69	0.22	0.73	81	164	146
MT	0.61	0.67	0.30	0.27	0.25	0.30	0.66	0.24	0.84	88	159	168
NT	0.53	0.66	0.22	0.23	0.30	0.30	0.66	0.24	0.91	76	163	167
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N Source (NS)												
0N	0.26 B	0.27 C	0.07 B	0.10 B	0.13 B	0.13 B	0.43 C	0.08 C	0.47 B	36 B	82 C	74 C
100ANN	0.57 A	0.74 A	0.22 A	0.25 A	0.29 A	0.29 A	0.66 B	0.26 AB	0.83 A	82 A	169 B	160 B
100PLN	**0.54 A**	0.54 B	0.28 A	0.23 A	0.26 A	0.28 A	0.71 B	0.20 B	0.84 A	77 A	152 B	160 B
200PLN	0.55 A	0.83 A	0.32 A	0.26 A	0.34 A	0.39 A	0.99 A	0.32 A	1.02 A	80 A	216 A	205 A
P > F (0.05)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0002	0.0006	<0.0001	<0.0001	<0.0001
Cropping System (CS)												
C-F	0.56	0.74	0.21	0.23	0.31	0.28	0.69	0.26	0.79	79	173	153
C-R	0.57	0.64	0.26	0.24	0.27	0.29	0.67	0.23	0.85	81	158	162
P > F (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactions												
T X CS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
T X NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter, 200PLN= 200 kg N ha^{-1} as poultry litter, C-F = cotton (summer) followed by fallow (winter), C-R= cotton (summer) followed by rye (winter)
††Treatment means followed by the same upper case letter are not significantly different from each other at $P \leq 0.05$

and the effect disappeared in later stages. Conservation tillage systems showed similar plant growth compared to conventional tillage at all stages of measurements. Application of PL recorded higher or equal performance in terms of growth components compared to AN at all growth stages. Winter rye cover cropping did not influence cotton plant growth at all stages. Rapid dry matter accumulation in leaves was observed between 30 and 61 DAP, whereas rapid growth in stem and total plant weight was observed between 61 and 97 DAP (Fig. 3). At 137 DAP, drastic reduction in leaf weight per plant was observed because of leaf senescence. Slight reduction in stem weight was also observed and it was attributed to movement of food reserves from stem to reproductive parts at maturity. Dry matter accumulation in reproductive parts at 97 and 137 DAP, and seed weight and lint weight per plant at 137 DAP were not significantly influenced by tillage and cropping system, and these were similar at 100 kg N ha^{-1} either with AN or PL sources of N.

Of the total plant weight, 71% of dry matter was accumulated in leaves at early growth stage (30DAP), and it was reduced to 51, 26, and 11% at 61, 97 and 137 DAP, respectively. At 61 DAS, almost equal quantity of dry matter was accumulated in leaves (51%) and stems (49%), and in later stages stem weight was reduced to 39% and 32% at 97 and 137 DAS, respectively. This was attributed to movement of carbohydrate reserves from stems to reproductive parts at later stages of growth. At 97 DAP, dry

Fig. 1: Temperature and monthly rainfall during the experiment, Belle Mina, Alabama, 2009

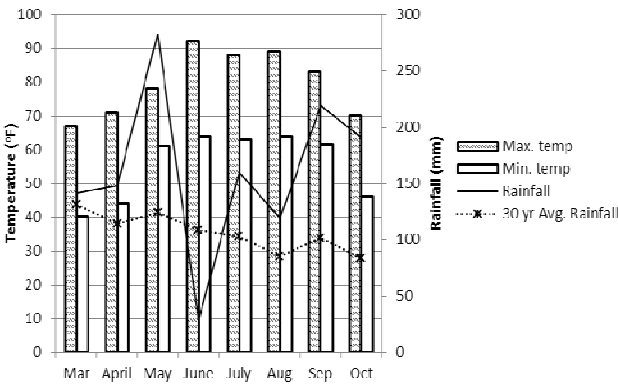


Fig. 2: Plant height and leaf weight of cotton in different growth stages as influenced by tillage and nitrogen source, Belle Mina, Alabama, 2009

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter

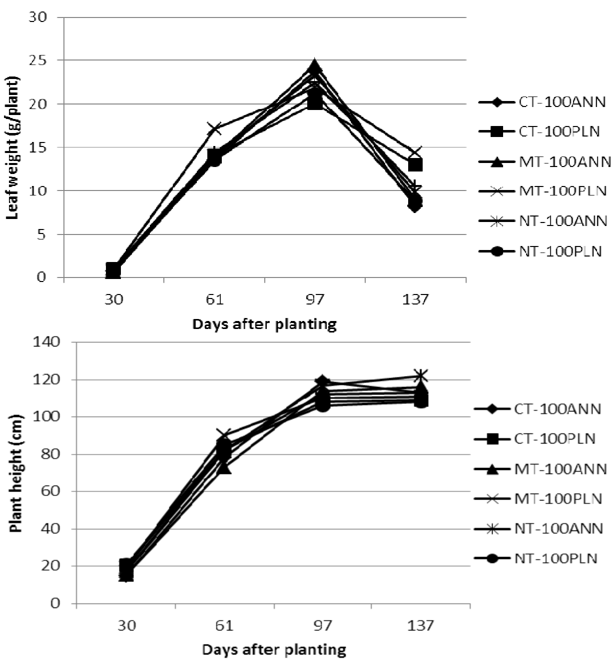
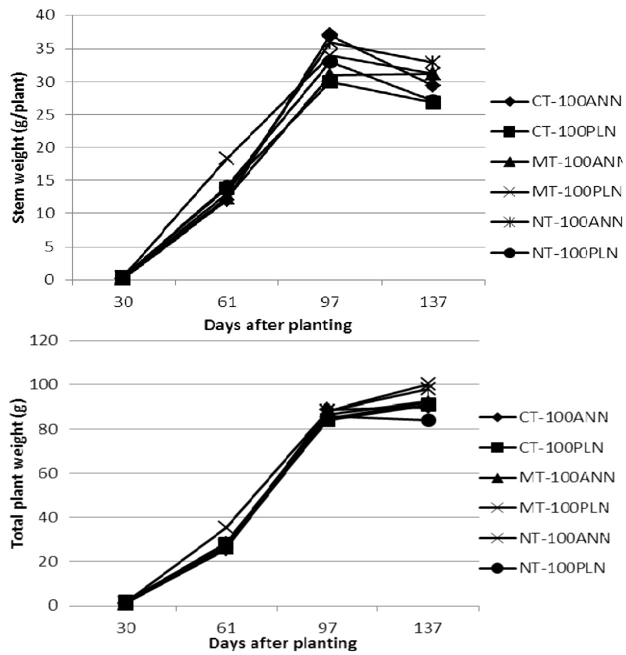


Fig. 3: Stem weight and total plant weight of cotton in different growth stages as influenced by tillage and nitrogen source, Belle Mina, Alabama, 2009

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter



matter partition into reproductive parts was recorded at 35% and it increased to 57% at maturity. Of the total dry matter accumulated in reproductive parts at maturity, 40% was partitioned into seeds and 30% each into lint and other reproductive parts (immature bolls, flowers & burs).

Nitrogen concentration in plant parts: Nitrogen concentration in different plant parts such as leaves, stem, reproductive parts and seeds were not significantly influenced by tillage and cropping system at all stages of observation (Table V). Results showed that under conservation tillage systems (NT & MT), the soil can supply equal quantity of nitrogen compared to that under CT system throughout the cropping season. Of the two nitrogen sources, AN at 100 kg N ha^{-1} recorded significantly higher N concentration in leaves at 97 DAP and in stem at 61 DAP compared to that of PL at the same rate. However, AN and PL at 100 kg N ha^{-1} recorded similar nitrogen uptake (kg N ha^{-1}) at all growth stages (Table VI).

Tillage and nitrogen source interactions did not influence nitrogen concentration in different plant parts except leaf N concentration at 61 DAP where application of AN recorded significantly higher N concentration compared to that of PL in all tillage systems (Fig. 5). As plant growth progressed, these differences in leaf N concentration due to N sources disappeared. At later stages of growth, plant N concentrations in different plant parts were similar in all tillage systems either with application of PL or AN at 100kg N ha^{-1} (Fig. 5 & Table V). This suggests that PL can supply equal quantity of N compared to AN throughout the cropping season even in no-till system. There is a general perception that nitrogen mineralization would be faster in conventional tillage system and subsequent nitrogen supply to the plants compared to that of no-till system, because N source gets thoroughly mixed up with soil. In contrast to this opinion, in the present study, PL supplied N as well as AN in no-till system throughout the cropping season despite the fact that PL was surface applied and was not mixed up with the soil. This could be attributed to the fact that in the present study the no-till plots were maintained for long (14 years) and they received PL for the same period and hence

Fig. 4: Dry matter partition into cotton plant parts at different growth stages as influenced by tillage and nutrient sources, Belle Mina, Alabama, 2009

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter

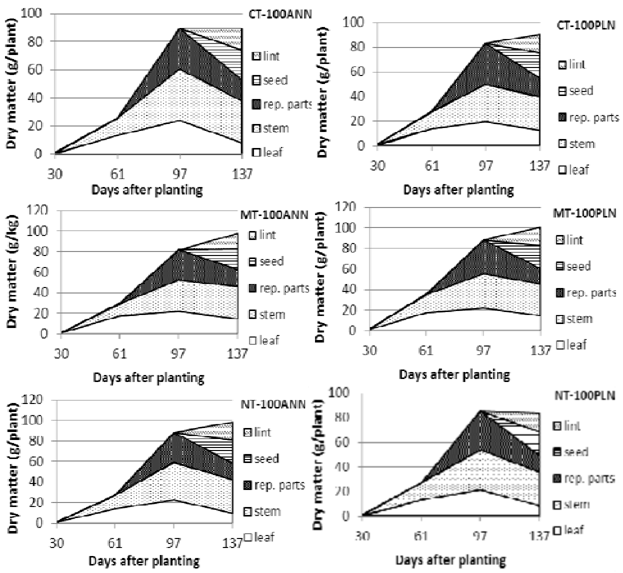
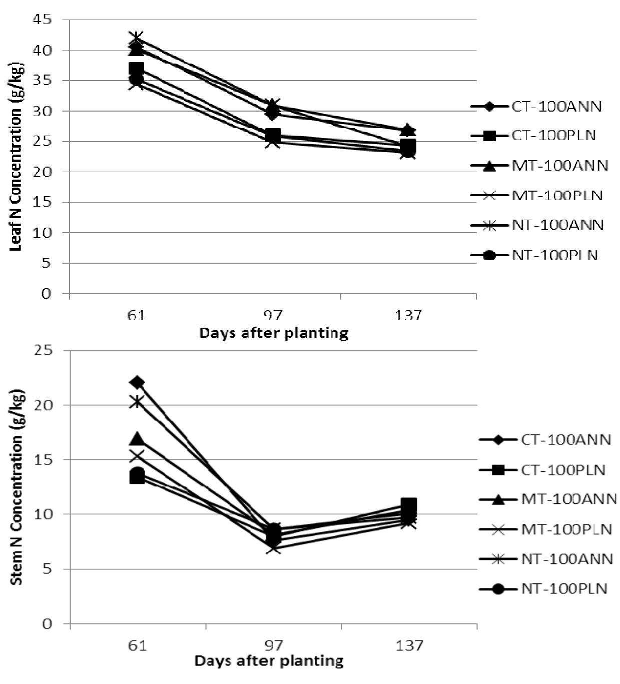


Fig. 5: Nitrogen concentration in leaves and stems at different growth stages as influenced by tillage and nitrogen sources, Belle Mina, Alabama



the mineralization process might be well stabilized. Typically only 50 to 60% of the total nitrogen in PL gets mineralized and become available for crop use in the first year and the rest will be available in succeeding years (Keeling *et al.,* 1995; Eghball *et al.,* 2002). Hence, in this experiment, the residual nitrogen pool as a result of long-term PL application is showing good response in terms of crop performance. In addition to this, more crop residues are normally left on the soil surface in no-till system than conventional tillage, thereby adding more organic matter and nitrogen pool to the soil. The highest leaf nitrogen concentration ranging from 34.5-42.0 g kg^{-1} was observed at 61 DAP but it dropped to 24.8-30.9 g kg^{-1} at 97 DAP and 23.1-26.9 g kg^{-1} at 137 DAP (Fig. 5). This is due to the fact that N moves from vegetative parts to reproductive parts at later stages of the growth. Stem nitrogen concentration was maximum at 61 DAP (13.4-22.0 g kg^{-1}) and it dropped to 6.9-8.7 g kg^{-1} at 97 DAP and then slightly increased to 9.2-10.9 g kg^{-1} at 137 DAP. At maturity (137 DAP), highest N concentration was recorded in seeds (37.6-42.1 g kg^{-1}) and the lowest in stems (9.2-10.9 g kg^{-1}). At all growth stages, nitrogen concentrations in plant parts were not influenced by tillage x cropping system interactions.

Nitrogen partitioning: Nitrogen extraction by above ground plant parts of cotton at different stages of growth was influenced by nitrogen sources, but not by tillage and cropping systems (Table VI). All tillage systems recorded similar nitrogen accumulation in different plant parts of cotton such as leaves, stems, reproductive parts and seeds at all stages of observation. Application of AN or PL nitrogen sources resulted in significantly higher nitrogen accumulation in vegetative and reproductive plant parts of cotton compared to that of control (0 kg N ha^{-1}). Poultry litter application at 100 kg N ha^{-1} recorded similar nitrogen partition into plant parts and total N uptake at all growth stages compared to that of AN at similar rate. Application of double rate of PL (200 kg N ha^{-1}) resulted in similar or higher nitrogen accumulation in plant parts compared to that of AN and PL at 100 kg N ha^{-1}.

Nitrogen partition into different plant parts was not significantly influenced by tillage x N source and tillage x cropping system interactions. All tillage systems recorded similar quantity of nitrogen accumulation in leaves at all stages of growth either with PL or AN at 100 kg N ha^{-1} (Fig. 6). Leaf N uptake at 61 DAP ranging from 0.48-0.64 g plant^{-1} increased to 0.53-0.76 g plant^{-1} at 97 DAP and then declined to 0.21-0.34 g plant^{-1} at 137DAP. Reduced nitrogen accumulation in leaves at maturity was attributed to reduced leaf area due to leaf senescence. Nitrogen partition into stems at 61 DAS ranged from 0.20 to 0.28 g plant^{-1} and it did not change much at later stages of growth (Fig. 5). Nitrogen partition into reproductive parts ranged 0.63-0.73 g plant^{-1} at 97 DAS and it declined to 0.18-0.30 g plant^{-1} at maturity. Nitrogen accumulation in seeds at maturity ranged 0.76-0.95 g plant^{-1}. Out of total nitrogen extracted by the cotton plants at 61 DAP, 70% was partitioned into leaves and rest into stems. At 97 DAP, maximum quantity of nitrogen was partitioned into reproductive parts (43%) and leaves (40%) and the rest into stems (17%). At maturity (137 DAP), major quantity of nitrogen i.e., 52% was partitioned into seeds and remaining nitrogen was

Fig. 6: Nitrogen accumulation in leaves and stems and total plant nitrogen uptake at different growth stages as influenced by tillage and nitrogen sources, Belle Mina, Alabama, 2009

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter

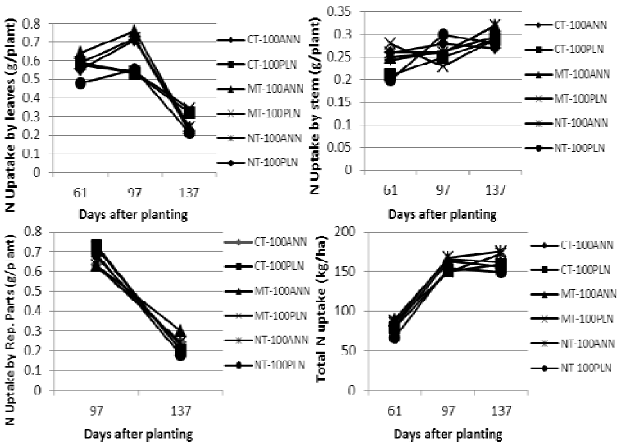
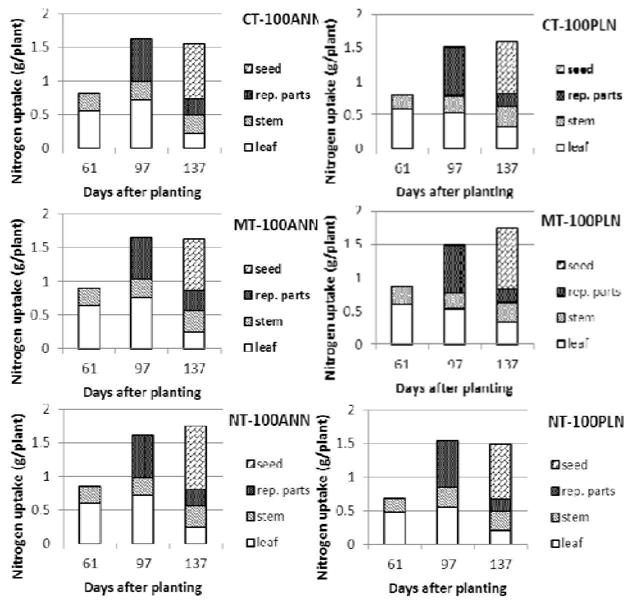


Fig. 7: Nitrogen partition into cotton plant parts at different growth stages as influenced by tillage and nitrogen sources, Belle Mina, Alabama, 2009

†CT= Conventional Tillage, MT= Mulch Tillage, NT= No Tillage, 100ANN= 100 kg N ha^{-1} as ammonium nitrate, 100PLN= 100 kg N ha^{-1} as poultry litter



distributed into leaves, stems and other reproductive parts (immature bolls, flowers & burs) at 16%, 18% and 14%, respectively.

Total nitrogen uptake by cotton: Total nitrogen uptake by cotton crop was significantly influenced by nitrogen sources at all observed growth stages (Table VI). Application of AN or PL at 100 kg N ha^{-1} recorded significantly higher total nitrogen uptake by cotton at all stages of growth compared to that of control (0 kg N ha^{-1}). The two nitrogen sources, AN and PL at 100 kg N ha^{-1}, recorded similar nitrogen uptake by cotton at all growth stages. As explained earlier, this could be attributed to long-term application benefits of PL. Application of a double rate of PL (200 kg N ha^{-1}) resulted in significantly higher nitrogen uptake at 97 and 137 DAP compared to that of AN and PL at 100 kg N ha^{-1}, but yield advantages were not observed with this higher nitrogen rate (Table IV). Our results are in agreement with findings of Adeli *et al.* (2007) in silt loam soils. They observed that application of PL at rates greater than 4.5 Mg ha^{-1}+67 kg ha^{-1} supplemental N, a total of around 150 kg N ha^{-1} (based on 60% N availability from PL in the first year), did not enhance cotton lint yield. Further, they also observed increased post-harvest residual NO_3-N concentration in the top soil, which signifies that the supplied N rate exceeded crop nutrient use potential. There is also risk of phosphorus buildup in top soil with higher rate of PL application (Adeli *et al.*, 2007; Reddy *et al.*, 2009), which is prone to surface runoff.

Conservation tillage systems (NT & MT) recorded similar nitrogen uptake by cotton at all growth stages as compared with conventional tillage system. This was reflected in growth and yields of cotton (Table III & IV). No-tillage recorded similar seed cotton yields (3729 kg ha^{-1}) compared to that of CT (3582 kg ha^{-1}). Significant positive and negative yield responses in cotton due to no-tillage have been reported earlier (Nyakatawa *et al.*, 2000; Raper *et al.*, 2000; Pettigrew & Jones, 2001; Schwab *et al.*, 2002). Reddy *et al.* (2009) observed similar cotton yields in NT system compared to CT system when nitrogen was supplied through inorganic fertilizers, they also observed 10-12% yield reductions in NT when nitrogen was applied through PL. However, other benefits in NT system over CT i.e., lower labor and equipment cost, reduced soil erosion and improved soil quality nullify such a slight yield reductions in NT. For a NT system it may take up to 3 to 5 years to become fully functional and provide long-term benefits of improved soil properties when changing from tilled to NT culture (Triplett & Dick, 2008).

Nitrogen uptake was also not influenced by tillage x nitrogen source and tillage x cropping system interactions. All tillage systems recorded similar total nitrogen uptake by cotton at all stages of growth either with AN or PL at 100 kg N ha^{-1} (Fig. 6). Of the total nitrogen extracted by cotton at maturity, 50% uptake was completed by early flowering stage (61 DAP) and 97% extraction was completed by boll development stage (97 DAP). This clearly shows that the cotton plant needs and extracts nitrogen vigorously till boll development stage and after that, nitrogen translocation takes place from vegetative parts to reproductive parts. In this experiment, application of PL supplied a similar quantity of nitrogen compared to AN throughout the cropping season in all tillage systems. The same was reflected in the seed cotton yields. All tillage systems recorded similar seed cotton yields either with AN or PL at 100 kg N ha^{-1} (Table IV). Winter rye cover crop did not influence nitrogen uptake.

CONCLUSION

Results of this experiment in 2009 showed that under long-term no-tillage (NT) system, the soil can supply equal quantity of nitrogen compared to conventional-tillage (CT) at all growth stages and this fact was reflected in growth and yield of cotton. Lack of fertilizer incorporation into the soil in NT did not decrease the nitrogen supply efficiency of nutrient source. Application of poultry litter (PL) at 100 kg N ha^{-1} recorded significantly higher growth components compared to ammonium nitrate (AN) at the early growth stage but the growth advantages disappeared at later growth stages. Similar yield and nitrogen uptake were observed with application of either poultry litter or ammonium nitrate. Application of a double rate of poultry litter (200 kg N ha^{-1}) resulted in significantly higher nitrogen uptake by cotton compared to PL or AN at 100 kg N ha^{-1}, but a yield advantage was not observed with this higher rate. Since external factors such as rainfall may have influence on nutrient loss through runoff from no-tillage plots where nutrient sources are surface applied, further studies are needed to confirm the results.

Acknowledgement: We appreciate the help of Bobby E. Norris Jr., Director and staff of the Tennessee Valley Research and Extension Center with field plot management. We are also thankful to Geetha Sajjala and Azimuddin for their help in collecting samples. This research was supported by a Specific Cooperative Agreement with USDA-ARS.

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(Received 10 August 2011; Accepted 07 October 2011)