CrossMark

REVIEW ARTICLE

Nitrogen fertilization and conservation tillage: a review on growth, yield, and greenhouse gas emissions in cotton

Adnan Noor Shah[1] · Javaid Iqbal[2] · Mohsin Tanveer[3] · Guozheng Yang[1] ·
Waseem Hassan[4] · Shah Fahad[3] · Muhammad Yousaf[5] · Yingying Wu[1]

Abstract Cotton is planted worldwide as a "cash crop" providing us fiber, edible oil, and animal feed as well. In this review, we presented a contemporary synthesis of the existing data regarding the importance of nitrogen application and tillage system on cotton growth and greenhouse gas (GHG) emission. Cotton growth and development are greatly influenced by nitrogen (N); therefore, proper N application is important in this context. Tillage system also influences cottonseed yield. Conservation tillage shows more promising results as compared to the conventional tillage in the context of cotton growth and GHG emission. Moreover, the research and knowledge gap relating to nitrogen application, tillage and cotton growth and yield, and GHG emission was also highlighted in order to guide the further studies in the future. Although limited data were available regarding N application, tillage and their interactive effects on cotton performance, and GHG emission, we also tried to highlight some key factors which influence them significantly.

Keywords Cotton · Greenhouse gases · Nitrogen management · Tillage · Sustainable agriculture

✉ Guozheng Yang
  ygzh9999@mail.hzau.edu.cn

[1] MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Sciences and Technology, Huazhong Agricultural University, Wuhan 430070, People's Republic of China

[2] Ghazi University, Dera Ghazi Khan, Punjab 32200, Pakistan

[3] National Key Laboratory of Crop Genetic Improvement, Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Sciences and Technology, Huazhong Agricultural University, Wuhan 430070, People's Republic of China

[4] Department of Soil and Environmental Sciences, Muhammad Nawaz Shareef University of Agriculture, Multan, Pakistan

[5] College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, People's Republic of China

Introduction

Cotton is a tropical crop and plays a considerable role in the economic development worldwide. Cotton is an important source of fiber, oil, and animal feed (Dai and Dong 2014). In China, 5.9 million ha of cropland is cultivated with cotton, corresponding to approximately 4 % of the total cultivating area, and on the other hand, the ongoing economic development has resulted in a sharp rise of inorganic N fertilizer consumption between 1980 and 2007 from 9.3 to 23.0 million t N (China Statistical Year book, 2008). The global 20 years' average (1993/94 to 2013/14) annual planted area is 33 million ha of cotton (source: Bremen Cotton Exchange 2014) producing about 26 million t of lint each year. Different crop husbandry practices such as fertilization especially nitrogen (N) and tillage system greatly influence the cotton yield (Howard et al. 2001). N is an important macronutrient that influences cotton growth significantly (Mokhele et al. 2012). Over and/or under N application from optimum rate resulted in reduced cotton growth and yield (Constable and Rochester 1988; Lokhande and Reddy 2015). Different management practices such as application rate, application methods, N fertilizer types, and their respective use efficiencies also influence cotton production (Larson et al. 2001). Cotton maturity is of big concern while considering N application (Dai and Dong 2014). Excess application of N causes delayed maturity (Pettigrew et al. 1996). Cotton requires high N demand (50–412 kg N ha^{-1}), which can develop suitable conditions for the

Springer

emission of greenhouse gases (GHGs) associated with high denitrification process (Scheer et al. 2008a; Zhang et al. 2008). Indeed, significant emissions of these GHGs have been observed from cotton fields across the globe (Scheer et al. 2008b). Moreover, greenhouse gas emissions from the cotton fields due to N fertilization and tillage practices were also discussed. Previously, available reports have revealed variable effects of tillage on cotton yield. Some researchers have reported better cotton growth and higher lint yield under conservation tillage as compared with conventional tillage (Daniel et al. 1999; Nyakatawa et al. 2000). However, some studies have observed no significant yield difference between these different tillage systems (Ishaq et al. 2001; Pettigrew and Jones 2001; Schwab et al. 2002). Triplett et al. (1996) have argued that the exact benefits of conservation tillage in cotton can only be observed after several years of conservation tillage practices. The present review attempts to highlight the role of N fertilization and conservation tillage on growth and yield of cotton and on GHG emission.

Cotton growth and yield in relation to nitrogen application

Nitrogen (N) is an important macroelement that plays a crucial role in growth and physiology of plants (Marschner 2001). Nonetheless, N stress in the form of N deficiency or excess greatly influences the cotton growth and yield by disrupting the several growth-promoting processes in cotton (Gerik et al. 1998; Lokhande and Reddy 2015). Jaynes et al. (2001) observed stunted growth of cotton with decreased leaf area, number of fruiting branches, and lint yield under N deficiency as compared to control with optimum N application. Availability of optimum N governs physiological growth and activity of cotton, while N limitation during the early growth stages resulted in reduced leaf expansion associated with decreased cell division and cell expansion (Chapin 1980; Tang et al. 2012).

Nitrogen deficiency also induces the competition for the translocation of N within plant. Lokhande and Reddy (2015) substantiated that during the reproductive growth of cotton, growing bolls have priority for plant assimilates, and as a result, the vegetative growth of cotton was suppressed. Nitrogen deficiency also reduced the fruiting pattern and boll formation in cotton. Gerik et al. (1998) observed the altered fruiting pattern and reduced boll size, boll weight, and number of bolls per plant per unit time with limited N supply as compared to N optimal condition.

Cotton fiber is the ultimate purpose of farmers in cotton cultivation. Cotton fiber is elongated and thickened single cell of seed epidermis, which achieves its maximum length in the early period of anthesis (15–20 days after anthesis) followed by cellulose deposition on secondary wall, giving rise to strength and maturity (Davidonis et al. 2004). N limitation during fiber development stage resulted in reduced fiber strength and quality. It has been reported that N deficiency decreased the fiber length and strength (Read et al. 2006) while increased the micronaire value (Reddy et al. 2004). A positive relationship was also found between fiber strength and N fertility (Fritschi et al. 2003).

The major portion of N is important for physiological growth of cotton, as leaf N is the major component of chloroplast. N deficiency resulted in reduced chlorophyll production with concomitant decline in photosynthetic activity and carbon assimilation in cotton (Zhao et al. 2003). It has been reported that cotton leaves accumulate about 44 g kg^{-1} of N (Reddy et al. 2004) under well-fertilized conditions. The strong relationship between leaf N and photosynthesis in cotton has been widely recognized and reported. N deficiency decreases leaf area and chlorophyll content, which lowers net photosynthesis rate (Radin and Boyer 1982). In another study, Reddy et al. (1996) reported a strong positive correlation among photosynthetic rate, stomatal conductance, and leaf N. They further substantiated that under limited N, Rubisco enzyme activity was reduced. Some other researchers also reported the strong association between leaf N content and photosynthesis in cotton (Shiraiwa and Sinclair 1993) with N deficiency adversely affecting lint yield through reductions in stem elongation, leaf expansion (Lu et al. 2001), photosynthetic and metabolic activities (Ciompi et al. 1996), and biomass production (Fritschi et al. 2003).

Cotton plants under deficient-N conditions produced significantly lower biomass 23 % per plant as compared to cotton that received sufficient amount of N (Lokhande and Reddy 2015). The reduction in biomass due to the insufficient N supply has been related to the reduction in leaf area (Fernáandez et al. 1996) and CO_2 assimilation rate (Reddy et al. 1997) that in turn restrict the reproductive growth of cotton.

Excess N application induced prolonged vegetative growth and delayed reproductive growth (Marschner 2001). Ayissa and Kebede (2011) observed delayed squaring, flower initiation, and boll opening of cotton plant significantly under higher N fertilization (92 kg ha^{-1}) than the unfertilized plot while intermediate application (68 kg ha^{-1}). The earliness attained in initial boll setting by the intermediate N rate, irrespective of cotton variety, could be due to optimum nitrogen demand of the crop for the heavy nutrient sinks of cotton bolls to be opened. At the same time, higher rate of nitrogen prolonged vegetative growth and delayed opening period of bolls.

Different studies indicated that under different N source and application methods, optimum N rate varies and showed different responses under different N rate (Table 1). Nitrogen use efficiency in cotton can also be influenced by the efficiency of N application methods. Different methods have been studied to supply N in cotton such as broadcasting (Boquet

Table 1 Cotton growth and yield response under different nitrogen rates

Nitrogen rate	Nitrogen source	Nitrogen application method	Effect on growth and yield	Reference
0, 75, 150, 225 kg N ha^{-1}	Urea	Basal and top dressing	Cotton showed optimum growth at 150 kg N ha^{-1} as compared to others.	Alitabar et al. (2012)
50, 150, and 200 kg N ha^{-1}	Urea	Three-split application	Cotton showed optimum growth at 150 kg N ha^{-1} as compared to others.	Baraich et al. (2012)
50, 100, and 150 kg N ha^{-1}	Urea and DAP	Broadcasting	Higher morphological growth at 150 kg N ha^{-1}, but photosynthetic activity was stagnant after 100 kg N ha^{-1}, indicating that it could not induce further partition in photosynthates toward the seed sink.	Kumbhar et al. (2008)
56 and 112 kg N ha^{-1}	Urea and DAP	Basal dose and additional side dressing	High fertilizer increased net photosynthetic rate (16 %) and chlorophyll contents (205 %) compared with low fertilizer	Zhao and Oosterhuis (2000)
0, 60, 120, 180 kg N ha^{-1}	Urea and DAP	Broadcasting	Optimum cotton growth at 120 kg ha^{-1} enhanced boll weight, seed cotton yield, and lint percentage but did not affect fiber quality.	Saleem et al. (2010)
0, 187, and 250 kg N ha^{-1}	Urea and DAP	Broadcasting	Application of 187 kg ha^{-1} resulted in maximum seed cotton, while high N dose resulted in excessive shedding of buds and bolls and less yield.	Khan et al. (2001)
50, 100, and 150 kg N ha^{-1}	SSP and urea	Side and top dressing	Higher reproductive growth was under 100 kg N ha^{-1}, but less number of bolls per plant was under 150 kg N ha^{-1} due to excessive vegetative growth.	Nadeem et al. (2010)

DAP diammonium phosphate, *SSP* single super phosphate)

and Breitenbeck 2000), split application (McConnell et al. 1993), and deep banding (Elberhar and Tupper 1988); nonetheless, the efficiency of each method varies with experimental conditions. Moreover, it was observed that split N application method significantly improved N fertilizer recovery (Sower et al. 1994). Cotton biomass and yield are also affected by the N split ratio assuming that the N rate is fixed. Yang et al. (2011) reported that the split ratio of 0 % at preplant, 40 % at first bloom, and 60 % at peak bloom harvested the highest biomass and yield when N was applied at 225 kg ha^{-1}. But cotton biomass accumulated the fastest from first bloom to peak bloom for each of the N split application ratios (Wang et al. 2010; Yang et al. 2011). Guo et al. (2010) found that the treatment of N application splitting into 40 % at preplant, 15 % at squaring stage, 23 % at first bloom, and 22 % at peak bloom had the highest cotton yield with the lowest abscission rate under drip irrigation in Xinjiang, China. Moreover, Yang et al. (2012) first-bloom stage gave the highest speed in biomass accumulation and suggested that one-time fertilization at first-bloom stage reduced labor costs without reducing the yield and thus could be a practical alternative for cotton fertilization.

Cotton growth and yield in relation to conservation tillage

Conservation tillage is defined as a set of tillage operations with minimum soil disturbance leaving a sufficient amount of residues on the soil surface (Alvarez 2005). Different

techniques, such as reduced tillage, mulch tillage, and zero or no tillage, are also employed to enhance the yield on sustainable basis (Hobbs et al. 2008). The effect of tillage on cotton yield is highly variable. Different studies reported better cotton growth with higher lint yield under no tillage as compared to conventional tillage (Daniel et al. 1999; Nyakatawa et al. 2000), while some indicated that cotton produced more number of bolls and showed better growth under conventional tillage as compared to conservation tillage (Ishaq et al. 2001; Pettigrew and Jones 2001; Schwab et al. 2002). Nonetheless, some researchers argued that the exact benefit of conservation tillage in cotton can only be observed after several years of using conservation tillage (Triplett et al. 1996). In this section, we briefly reviewed and summarized (Figs. 1 and 2) possible reasons of cotton yield increment under conservation tillage as compared to conventional tillage.

Weed management is one of the important issues in cotton production. Although poor weed control and drastic weed infestation are the major obstacles in the adoption of conservation tillage worldwide (Buhler et al. 1994; Fahad et al. 2015), nonetheless, conservation tillage promotes residue retention on soil surface and thus reduces weed infestation due to shading effect or cooler temperature (Locke et al. 2002). Bajwa et al. (2014) documented that weed management under conservation tillage depends on weed type, depth of weed seeds present in soil, and intensities of conservation tillage over different periods of time. Weed responses to conservation tillage system vary with the location and the weed species in cotton fields. Therefore, it is impossible to develop a set of specific guidelines for managing weeds in conservation tillage

Fig. 1 Comparative cotton growth under conservation tillage (a) vs conventional tillage (b) (picture courtesy; Adnan Noor Shah, Huazhong Agricultural University, China)
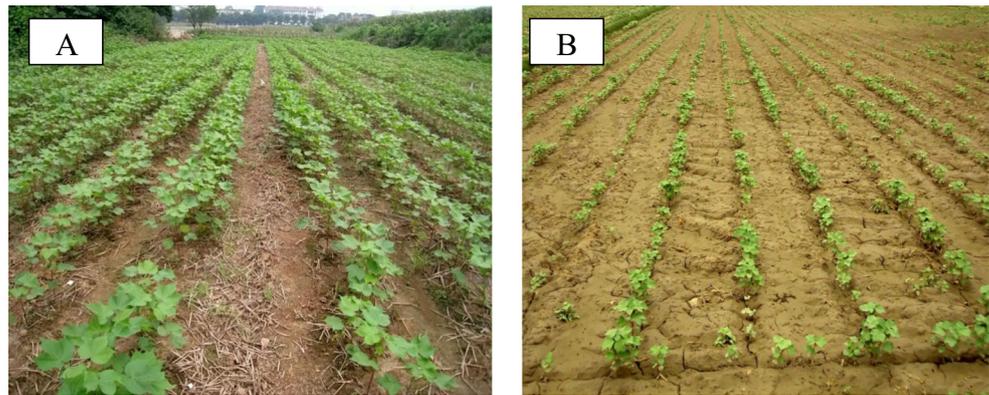

systems for sustainable cotton production. Nonetheless, integrated weed management options can be used while adopting conservation tillage for cotton.

Mulching and residue retention on soil surface due to conservation tillage is another crucial factor that can influence plant growth and yield (Yang et al. 2013). Cotton is a tropical summer crop, and water availability during cotton germination is one of the biggest obstacles in maintaining optimum plant population of cotton per unit area (Ayissaa and Kebede 2011). Nyakatawa and Reddy (2000) substantiated that surface residue retention under conservation tillage resulted in increased soil moisture contents, thus increasing the cottonseed germination, root growth, and lint yield compared with conventional tillage. Nonetheless, poor root penetration and difficulties in obtaining adequate stands and weed control have been observed to reduce cotton yields in no tillage (Schertz and Kemper 1994; Triplett et al. 1996). Veiga et al. (2008) reported that the stubble incorporation under conservation tillage improved the soil microbial activity, with concomitant increase in infiltration rate, fast drainage, aggregate stability, hydraulic conductivity, and redox potential. Soil losses due to erosion under conventional tillage occur due to the loosening and pulverizing effects of heavy tillage, while conservation

avoids such losses, as soil aggregates bind together due to high concentration of organic matter in soil which ultimately increases the cotton yield (Hutchinson et al. 1995). Soil hydraulic conductivity under conservation tillage is pertained to be more due to increased fauna activity resulting in large macropores, while soil under conventional system exhibited less macropores and hydraulic conductivity (Ferreras et al. 2000). Saturated hydraulic conductivity is found to be high in tilled soils due to the loosening of soil at the beginning of season, while at the end of the season, all particles were settled down and resulted in reduction of hydraulic conductivity (Shaver et al. 2002). Crop residue retention can improve soil nutrient status. For instance, the replacement effects of potassium fertilizer by various wheat straw incorporation rates can at least partly, even totally, replace chemical potash according to soil available K concentration in actual cotton production (Sui et al. 2015). In mulch tillage, stubbles on the soil surface limit raindrop action and hard crust formation (Gilley 1995). In addition, residues slow down surface runoff and increase infiltration rate. Bezborodov et al. (2010) noted that cotton yields were up to 800 kg ha^{-1} higher and crop water productivity (lint + seed) up to 0.47 kg m^{-3} greater in the mulching treatments than the farmers' managed fields with

Fig. 2 Summary of the effects of conservation tillage and related factors on cotton growth and yield
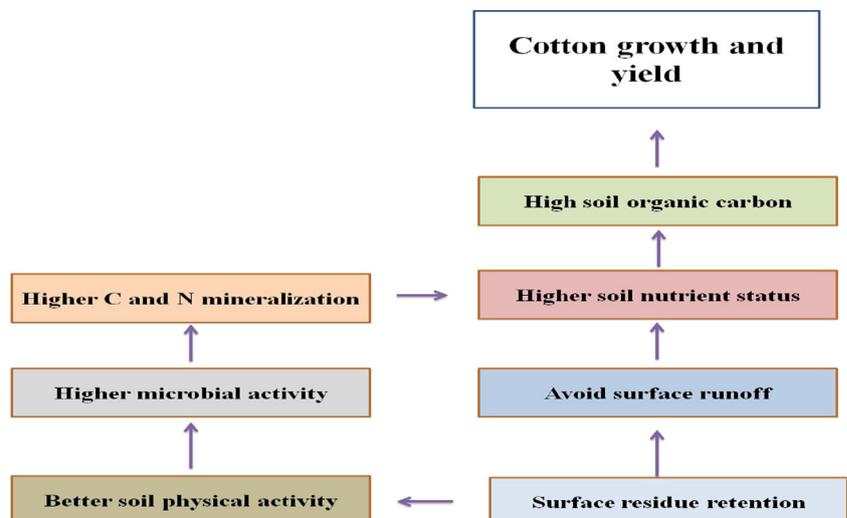
conventional practices in the same region. In another study, mulching increased seed cotton yield by 36.1 % as compared to no-mulch or conventional tillage system (Dong et al. 2005). Yoo et al. (1988) found that reduced tillage with winter wheat as cover crop was the most effective in reducing the surface runoff, sediment, and nutrient losses while maintaining comparable cotton yield. They also observed that runoff and sediment concentrations from conventional tillage system were high during the "critical period" (from planting to the last cultivation of the conventional tillage system), while some other researchers (Mueller et al. 1984) have shown the opposite. Differences in runoff volumes among tillage systems have been attributed to the varying effects of tillage on surface conditions and residue cover (Lindstrom and Onstad 1984). Andraski et al. (1985) reported that the tillage practices affect the runoff volumes and peak flows of surface runoff. Besides the amount of residue retention in soil, soil texture also influences nutrient uptake; for example, K uptake by seed cotton and cotton plant increased by 201.65 and 226.7 % than that of control, respectively, while on Dafeng sandy loam, potassium uptake by seed cotton and cotton plant was increased by 47.2 and 37.1 % in response to wheat straw incorporation, respectively.

Sustainability of the farming system can be improved by combining winter cover crops with conservation tillage. Cotton yield is often improved by planting winter cover crops in conservation tillage systems (Hutchinson et al. 1995; Sainju et al. 2006) because cover crops provide additional residues that act as mulch in conservation tillage, thereby improving soil moisture and germination of cotton seedlings (Boquet et al. 2004). Soil carbon (C) mineralization is governed by soil organic matter (SOM) and is important for improving soil fertility. Zero tillage retains sufficient amount of organic residue over soil surface pertained to be efficient in replenishing SOM pool, while conventional tillage decreases SOM because of less incorporation of crop residues in soil (Balesdent et al. 2000). Continuous soil stirring led to oxidation of organic matter; contrarily no tillage sequestered 67 to 512 kg C ha^{-1} per year than conventional tillage (McConkey et al. 2003). Sainju et al. (2006) attributed the higher cotton growth and lint yield under conservation tillage to better soil physical, chemical, and biological properties as compared with conventional tillage. Besides C sequestration, conservation tillage also increases the availability of nutrient in soil. Van Den Bossche et al. (2009) substantiated that no tillage reduced the N losses by increasing N mineralization and enhanced the N use efficiency than conventional tillage (Van Den Bossche et al. 2009). Placement and accumulation of plant residues on soil surface increase the soil organic carbon contents with concomitant increase in microbial activity (Amato and Ladd 1992). The enhanced microbial activity increases N mineralization, pertaining to more in upper soil surface, which consequently increased the crop production (Schimal et al. 2004). Placement and accumulation of plant residues on soil surface increase the soil organic carbon contents with concomitant

increase in microbial activity (Qiu et al. 2014). The enhanced microbial activity increases N mineralization, pertaining to more in upper soil surface which consequently increased the crop production (Paul 2014). Studies suggest that conversion of conventional till (CT) to no till (NT) can sequester atmospheric CO_2 by 0.1 % ha^{-1} at the 0–5-cm soil depth every year, a total of 10 t in 25–30 years (Lal and Kimble 1997). Sequestration of C in the soil by adopting no tillage can also conserve N, because soil organic carbon (SOC) and total N levels are highly related (Sainju et al. 2002). However, SOC and STN levels below the 7.5-cm depth can be higher in tilled areas, depending on the soil texture, due to residue incorporation at greater depths (Clapp et al. 2000). Bayet et al. (2006) found that compared to conventionally tilled soil, the C stocks in no-till sandy clay loam Oxisol increased by 2.4 Mg ha^{-1} (C sequestration rate = 0.30 Mg ha^{-1} year^{-1}) and in the clayey Oxisol by 3.0 Mg ha^{-1} (C sequestration rate = 0.60 Mg ha^{-1} year^{-1}). The mean rate of C sequestration in the no-till Brazilian tropical soils was estimated to be 0.35 Mg ha^{-1} year^{-1}, similar to the 0.34 Mg ha^{-1} year^{-1} reported for soils from temperate regions but lower than the 0.48 Mg ha^{-1} year^{-1} estimated for southern Brazilian subtropical soils. Feng et al. (2003) reported that the no-till treatment increased SOC and total nitrogen contents in the surface layer by 130 and 70 %, respectively, thus significantly increased cotton yield. Moreover, zero tillage along with adequate amount of crop residues minimizes N leaching (Sainju et al. 2006). N accumulation in the soil under conservation tillage by cotton may be partially masked by soil potential N mineralization (Sweeney and Moyer 2004). Karlen et al. (2001) showed that tillage system has a direct impact on N transport and its destination by altering soil physical properties peculiarly mineralization of organic contents, macropores, and available water. Cotton lint yield and N uptake were as good as or better in no till than in strip till and chisel till (Sainju et al. 2006). Conclusively, lower production cost and greater environmental benefits of reduced soil erosion and N leaching and increased C sequestration in conservation tillage make conservation tillage more promising for cotton production as compared to conventional tillage (Smart and Bradford 1999; Paxton et al. 2001). Feng et al. (2003) explained that how conservation tillage practices improve soil quality and sustainability in a cotton cropping system and suggested that during the growing season, changes in the microbial community may be primarily determined by soil conditions responding to cotton growth and environmental variables such as moisture and temperature; during fallow or prior to cotton establishment, community changes associated with tillage practices become more pronounced.

Greenhouse gas emission

In the current scenario of agriculture and climate change, sequestration of C in the soil is necessary to increase soil C pool

for C trading and for mitigating greenhouse gas emissions. This can be accomplished by the adoption of novel soil and crop management practices for a long term, which will not only increase soil C but also improve the soil quality and increase economic crop production. Likewise, N sequestration is another environmental issue and is needed to be investigated to reduce the rate and cost of N fertilization, N leaching, and N_2O emission. Conservation tillage is reported as an effective approach in mitigating emanation of greenhouse gases and sequestration of C and N in soil. Furthermore, N fertilization triggers the release of greenhouse gases from arable crop fields. This section consists of two subsections science pertaining to greenhouse gas emission (1) under conservation vs conventional tillage system and (2) under different N management practices. More possible effects of these greenhouse gases on cotton production and further than can reduce greenhouse gas emissions were also discussed.

Greenhouse gas emission in relation to N application

The release of greenhouse gases can also be affected by the type of N fertilizer application method, timing of application, placement of N, and N rate (Fig. 3). Availability of N and its losses are greatly influenced by its placement in soil and timing of N application. Venterea et al. (2005) found a significant interaction of tillage and N placement method on greenhouse gas emission and observed that N_2O release was higher under no tillage as compared with conventional tillage when N was applied at post emergence by broadcasting, nonetheless an opposite effect was noted when N was either injected or broadcasted at pre-planting. N is volatile in nature, thus its contact with oxygen could result in release of N as N_2O in air but this is not in case conventional tillage. Breitenbeck and Bremner (1986) noted that soil injection of anhydrous NH_3 at the depth of 30 cm caused 107 % higher N_2O release as compared with the soil injection at 10 cm. They also found that the effect of depth of application of anhydrous NH_3 on emission of N_2O was less when this fertilizer was applied at a rate of 225 kg N ha^{-1}. While it is suspected that anhydrous NH_3 may

possibly inhibit nitrifying bacteria and allow the accumulation of nitrite in soil. Venterea and Stanenas (2008) observed no increase in denitrification with substantially no release of N_2O at the depth of 30 cm under aerobic conditions. Placement of N on soil surface or at more depth resulted in higher N loss either by volatilization or by the release of N_2O under irrigated conditions. Research comparing the surface-applied urea to urea placed in a band below and to the side of the seed-row showed that N_2O emissions were higher under broadcasting compared with band placement (Hultgreen and Leduc 2003). Conclusively, placement of N at proper depth is of significant importance in the increasing N use efficiency in cotton, thus more research is required to study this aspect under different tillage systems and different agro ecological zones.

N_2O release also depends on the type of chemical fertilizer use; e.g., Tenuata and Beauchamp (2003) compared release of N_2O from different N fertilizer sources under field and laboratory conditions and observed a decreasing trend of N_2O production from urea, ammonium sulfate and calcium sulfate. They further recorded that moisture contents also interferes with the release of N_2O under aerobic conditions for instance release of N_2O was higher when N was supplied from urea than with other fertilizer with only fewer differences at high moisture contents. The authors concluded that this observation warrants more research since ammonium phosphate is commonly used and because of the possible implication of P status impacting N_2O emissions from N fertilizers. Harrison and Webb (2001) stated that it is difficult to say with any certainty if a strategy based on urea or ammonium nitrate would result in the smaller N_2O emissions. Contrarily, More recent comparisons among urea, NH_4-based and NO_3-based N source have shown higher emissions of N_2O from urea (Tenuta and Beauchamp 2003), and higher N_2O emissions from NH_4-based N fertilizers compared to NO_3-based fertilizers (Velthoff et al. 2003; Tenuta and Beauchamp 2003). This higher emission with NH_4-based fertilizers may be related to potential NO_2 accumulation or N_2O production during nitrification (Venterea and Stanenas 2008). Bouwman et al. (2002) reviewed numerous studies and

Fig. 3 Different fertilizer management approaches influence GHG emission
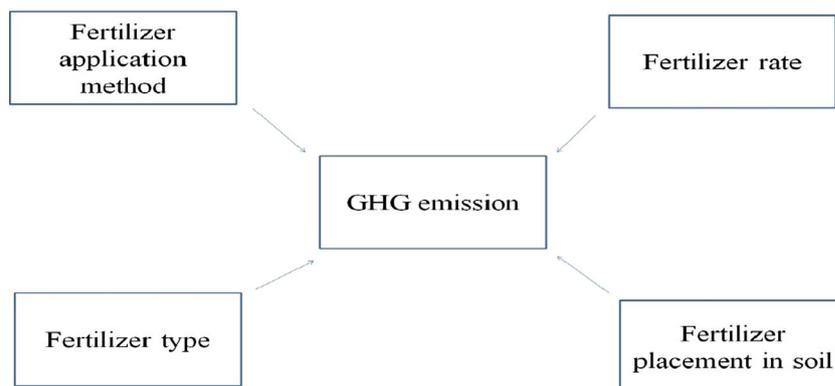
reported N_2O emissions appear to be lower for NO_3-based fertilizers compared to NH_4-based fertilizers and organic or synthetic-organic sources. Yet, one might expect a potentially higher N loss with an abundance of NO_3-N in soil systems from NO_3-based fertilizers compared to other N fertilizers, since NO_3 and NO_2 are essential for denitrification (Coyne 2008; Alexander 1977). However, anhydrous NH_3 has exhibited higher N_2O emissions in several studies comparing it with other N sources (Breitenbeck and Bremner 1986; Venterea et al. 2005). Different studies reported emission and flux of different GHGs in cotton under different nutrient regimes (Table 2).

Greenhouse gas emission in relation to conservation tillage

Intensive tillage facilitates the microbial decomposition of organic matter at higher rates as compared with minimum tillage which produces CO_2 (Reicosky et al. 1997). Different researchers suggested that the reduction in tillage intensity could be beneficial in reducing CO_2 emission from soil and could be helpful in the sequestration of C in soil (Potter et al. 1998; Reicosky et al. 1997). Conservation tillage involves the placement of stubbles on soil surface to avoid soil erosion and addition of organic matter and for moisture conservation (Farooq et al. 2011). This technique can mitigate emission of N_2O gas by affecting directly NO_3 availability or by modifying indirectly the soil microclimate and cycling of C and N. In many regions, soil C storage increased and potential of global warming decreased by appropriate conservation tillage (Lal 2003). There is a conflict among different researchers regarding the extent of the release of greenhouse gases under different tillage systems, and there is no clear positive or negative relation of the mitigation of greenhouse gases and tillage system. It appears that, in some regions, the benefits of minimum tillage include an increase in stored SOM, both organic C and N, to a greater degree than any potential increase in N_2O emissions, so that the net global warming potential (GWP) decreases. In other studies, the GWP was slightly increased by switching from conventional tillage to conservation or no

till (Gregorich et al. 2001; Lal 2003). Malhi et al. (2006) observed that in the region of Alberta Parkland, no tillage considerably reduced the emission of greenhouse gases. In a Canadian prairie region, Malhi et al. (2006) noted the higher N losses in the form of N_2O under conventionally tilled plots as compared to no-tilled plots. Halvorson et al. (2002) noted the reduced N_2O emissions under no till compared to conventional till, when averaged across years and four N rates. Hulugallc (2000) observed higher C sequestration under different cotton-based cropping systems under conservation tillage as compared with conventional tillage. Although it is well evident that the conservation tillage reduced the emanation of greenhouses gases, nonetheless, little information has been reported so far pertaining to the release of greenhouse gases in cotton fields and their effects on cotton growth and productivity.

Interactive effects of N application and conservation tillage on cotton growth and yield and GHG emission

Interactive effects of N application and conservation tillage on cotton growth and yield

The availability and management of N under conservation tillage depend on numerous factors, which ultimately affect the cotton yield. Excess and imbalanced N application under intensive or conventional tillage has been known to cause groundwater contamination through N leaching. Furthermore, overapplication of N increases cost of production by millions of dollars each year (Koch et al. 2004). Howard et al. (2001) stated that the optimum N application is the key for determining a wide range of cotton plant yield variables including plant size, fruiting intensity, boll retention rate, boll size, and total boll number per plant.

Nitrogen fertilization rate for optimizing cotton yield can vary with the type of tillage and cover crop. Boquet et al. (2004) reported that the cotton yields were lower in no tillage than in surface tillage without applied N, but with optimum N

Table 2 Reported GHG emission and their fluxes in different countries in cotton

Place of study	GHG under study	GHG emission	GHG flux	Reference
Pakistan	N_2O	3.2 kg ha^{-1}	2.33 g N ha^{-1} day^{-1}	Mahmood et al. (2008)
China	N_2O	2.6 kg ha^{-1}	30 µg N m^{-2} h^{-1}	Liu et al. (2010)
China	NO	0.8 kg ha^{-1}	8.8 µg N m^{-2} h^{-1}	Liu et al. (2010)
Uzbekistan	N_2O	0.9 to 6 kg ha^{-1}	3000 µg N m^{-2} h^{-1}	Scheer et al. (2008a, b)
Australia	CO_2e	127, 127, and 1634 kg ha^{-1} (for solid-plant, double-skip, and irrigated cotton farming systems, respectively)	–	Maraseni et al. (2010)

rate, yields were higher in no tillage. They also found that higher N rate was required to optimize cotton yield following wheat (Triticum aestivum L.) or no cover crop in no tillage and surface tillage, but no N was required following hairy vetch (Vicia villosa Roth) in either tillage practice. This suggests that N fertilization rates to cotton can be reduced by using legume cover crops, such as hairy vetch and red clover (Trifolium pratense L.), regardless of tillage practices (Hargrove 1986; Blevins et al. 1990). On the other hand, it is not surprising to observe higher soil inorganic N with increasing N fertilization rates, because crops are unable to take 100 % of the applied N (Bergstrom and Kirchmann 2004; Bundy and Andraski 2005). Probably, crop N uptake and N loss due to leaching and/or volatilization occurred more rapidly with N fertilization than with cover crops where the rate of N mineralization is slower (Sainju and Singh 2001; Bergstrom and Kirchmann 2004). Boquet et al. (2004) reported that cotton lint yield and N uptake increased with increasing N fertilization rates from 0 to 118 kg N ha^{-1} with wheat cover crop or native cover but decreased with hairy vetch. The tolerance of cotton lint yield following rye to high N rates was probably related to N immobilization caused by high C/N ratio of rye residue (Dabney et al. 2001). It may also be possible that unidentified factors retard cotton's vegetative growth in wheat residue (Hicks et al. 1989). Nitrogen fertilizer rate also affects the cotton maturity, as in case of late-planted cotton, excess N application could not trigger vegetative growth but increase unnecessary growth of unwanted branches and delayed cotton maturity. In another study, Larson et al. (2001) observed that no-tilled cotton followed by hairy vetch cover required 68 lb acre^{-1} less applied N to maximize profits when compared with no cover. This reduction in the N fertilizer requirement for vetch was considerably larger than the N savings estimated for cotton production. Results of Sainju et al. (2005) suggested that conservation tillage with the inclusion of cover crop and reduced rate of N fertilization can sustain cotton lint yield better than conventional tillage with full rate of N fertilization.

Inclusion of cover crops in winter acts as additional source of N fertilization in cotton under conservation tillage system. Larson et al. (2001) reported that improved soil quality with winter covers in cotton and conservation tillage may enhance the yield response to N fertilizer. Roberts et al. (1998) estimated a larger reduction in the N fertilization rate required to maximize profit in the presence of legumes as cover crops. Presence of cover crop considerably influences soil inorganic N; however, the amount of inorganic N depends on the conservation tillage and the type of cover crop. Sainju et al. (2006) observed that inorganic N was higher in soil where hairy vetch was used as cover crop as compared to winter rye in no tillage. They further observed that tillage × cover crop interaction was significant for lint yield and N uptake. Sainju and Singh (2001) found hairy vetch as the most efficient cover crop in increasing N in soil, and this was because

of its higher N concentration and lower C/N ratio, rapid decomposition in the soil, and soil N enrichment more than rye. Moreover, hairy vetch releases about half of its N within 2–4 weeks after the residue was incorporated into the soil (Stute and Posner 1995). Other benefit of using cover crops in cotton production is the reduced N losses either by leaching or by volatilization. Different studies have indicated that it is not surprising to observe higher soil inorganic N with increasing N fertilization rates, because crops are unable to take 100 % of the applied N (Bergstrom and Kirchmann 2004; Bundy and Andraski 2005). Probably, crop N uptake and N loss due to leaching and/or volatilization occurred more rapidly with N fertilization than with cover crops where the rate of N mineralization is slower (Sainju and Singh 2001; Bergstrom and Kirchmann 2004).

Interactive effects of N application and conservation tillage on GHG emission

Fertilizer source and tillage interactions can result from differences in soil water content and bulk density and differences in soil nitrite accumulation among N sources and may depend on whether nitrification or denitrification dominates in the crop and soil system (Venterea and Stanenas 2008). Interactions between N sources and tillage systems often occur. Venterea et al. (2005) concluded that emissions of N_2O with urea were higher under no till and conservation tillage compared to conventional tillage, while no differences among tillage systems were observed with urea. With anhydrous NH_3, N_2O emissions were greater with conventional tillage than the other two tillage systems. As reported by Breitenbeck and Bremner (1986), anhydrous NH_3 resulted in higher N_2O emissions compared to the other two sources and their application methods. However, in a study by Venterea et al. (2005), the fertilizer N source effects were more confounded with placement methods. Higher application of N resulted in accumulation of N as nitrate in soil and reduced the N availability to cotton (Legg and Meisinger 1982). The use of appropriate N rates can help to minimize the soil accumulation of NO_3-N. Apparently, reducing the amount of applied N cannot be a solution as N application below economic requirement of plant could result in overmining of SOC and long-term decrease in soil productivity. Furthermore, when N application rate exceeds agronomic N threshold level, the rate of N_2O emission also increases. For instance, Malhi et al. (2006) noted that in a particular cropping study, overdose of N <80 kg ha^{-1} resulted in higher release of N_2O. Likewise, Grant et al. (2006) observed that N rates more than 100 kg ha^{-1} resulted in higher N_2O emission in cornfields. Little information is available regarding the dose-dependent relation of N and N_2O emission in cotton; therefore, future studies should be directed in this regard.

The exact mechanism of N loss has not been identified in cotton; nonetheless, (Chua et al. (2003) identified denitrification as the major process in N losses from cotton fields under irrigated conditions. Rochester et al. (1996) reported that denitrification can cause N fertilizer loss up to 60 %. In another study, Rochester (2003) used ^{15}N balance approach and estimated that roughly 2 kg N ha^{-1} (1.1 % of the N applied) was lost as N_2O during the cotton-growing season. Skiba and Smith (2000), on other hand, found that soil moisture also played a significant role in the release of N_2O or NO by influencing the nitrification and denitrification in the soil. Different studies indicated that the high requirement of N and irrigation water makes potentially favorable conditions for the emission of N_2O and NO by provoking denitrifying microbial activity in the agricultural soil (Zheng et al. 2000; Hou et al. 2007; Zhang et al. 2008). Indeed, significant emissions of these N gases have been observed from cotton fields across the globe (Mahmood et al. 2008; Scheer et al. 2008a, b) and the N recoveries from the crop are usually low, e.g., less than 60 % of the fertilizer N (Hou et al. 2007; Norton and Silvertooth 2007). Ludwing et al. (2001) substantiated that the higher availability of soil mineral N was positively correlated with N_2O and NO emissions. Liu et al. (2010) studied the mechanism for the release of N_2O and NO from cotton under N fertilization by urea and found that hydrolysis of urea yields ammonium, which can be nitrified and abruptly increased soil NH_4^+ and NO_3^- concentrations. NO_3^- acts as a substrate for nitrification and denitrification and thus converts into N_2O and NO. At rates of N application that increase crop residue return to the soil, decreases in soil bulk density can occur. Deep soil sampling is required to accurately monitor the increase in soil organic C that results from different rates of N. They also found that the highest emissions (0.85 and 0.22 kg N ha^{-1}) of N_2O and NO, respectively, were observed directly after the N fertilization, which was responsible for 32.3 and 29.0 % of the annual total N_2O and NO loss. Information regarding N transport and movement in different kinds of soils under conservation tillage is still limited, and further studies are required to examine the extent of N leaching or volatilization as an experimental research perspective in addition to cotton production. Areas are to be studied for better understanding of N management and conservative tillage on the effects of cotton growth and yield and GHG emission.

Conclusion

Cotton is an important fiber crop; however, crop husbandry practices such as tillage or nitrogen application caused a significant influence on cotton growth and development. This review concludes that conservation tillage such as zero tillage or mulch tillage is effective not only in increasing cotton production but also in improving soil structure and water conservation in soil. Higher nitrogen application resulted in delayed maturity, which caused significant lint yield reduction; therefore, optimum N application is important for sustainable cotton production and control in the emission of GHGs as well.

References

Alexander M (1977) Mineralization and immobilization of nitrogen: introduction to soil microbiology, 2nd edn. Wiley, New York, pp. 136–247

Alitabar RA, Salimbeck R, Alishah O, Andarkhor SAA (2012) Interactive effects of nitrogen and row spacing on growth and yield of cotton varieties. International Journal of Biology 4(3):124

Alvarez R (2005) A review of nitrogen fertilizer and conservation tillage effects on soil organic carbon storage. Soil Use Manag 21:38–52

Amato M, Ladd JN (1992) Decomposition of 14 C-labelled glucose and legume material in soils properties influencing the accumulation of organic residue C and microbial biomass C. Soil Biol Biochem 24: 455–464

Andraski BJ, Mueller DH, Daniel TC (1985) Phosphorus losses in runoff as affected by tillage. Soil Sci Soc Am J 49:1523–1152

Ayissaa T, Kebedeb F (2011) Effect of nitrogenous fertilizer on the growth and yield of cotton (Gossypium hirsutum L.) varieties in Middle Awash, Ethiopia. J Drylands 4:248–258

Bajwa AA (2014) Sustainable weed management in conservation agriculture. Crop Protec 65:105–113

Balesdent JC, Chenu BM (2000) Relationship of soil organic matter dynamics to physical protection and tillage. Soil Tillage Res 53: 215–230

Baraich AHK, Jamali LA, Salarzi AU (2012) Effect of nitrogen application rates on growth and yield of cotton varieties. Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences 28: 115–123

Bayer C, Martin-Neto L, Mielniczuk J, Pavinato A, Dieckow J (2006) Carbon sequestration in two Brazilian Cerrado soils under no-till. Soil Tillage Res 86:237–245

Bergström L, Kirchmann H (2004) Leaching and crop uptake of nitrogen from nitrogen-15-labeled green manures and ammonium nitrate. J Environ Qual 33:1786–1792

Bezborodov GA, Shadmanov DK, Mirhashimov RT, Yuldashev T, Qureshi AS, Noble AD, Qadir M (2010) Mulching and water quality effects on soil salinity and sodicity dynamics and cotton productivity in Central Asia. Agric Ecosyst Environ 138:95–102

Blevins RL, Herbek JH, Frye WW (1990) Legume cover crops as a nitrogen source for no-till corn and grain sorghum. Agron J 82: 769–772

Boquet DJ, Breitenbeck GA (2000) Nitrogen rate effect on partitioning of nitrogen and dry matter by cotton. Crop Sci 40:1685–1693

Boquet DJ, Hutchinson RL, Breitenbeck GA (2004) Long-term tillage cover crop and nitrogen rate effects on cotton. Agron J 96:1443–1452

Bouwman AF, Boumans LJM, Batjes NH (2002) Modeling global annual N_2O and NO emissions from fertilized fields. Biogeochem Cycles 16.

Breitenbeck GA, Bremner JM (1986) Effects of rate and depth of fertilizer application on emission of nitrous oxide from soil fertilized with anhydrous ammonia. Biol Fertil Soils 2:201–204

Buhler DD, Stoltenberg DE, Becker RL, Gunsolus JL (1994) Perennial weed populations after 14 years of variable tillage and cropping practices. Weed Sci 42:205–209

Bundy LG, Andraski TW (2005) Recovery of fertilizer nitrogen in crop residues and cover crops on an irrigated sandy soil. Soil Sci Soc Am J 69:640–648

Chapin FS (1980) The mineral nutrition of wild plants. Annu Rev Ecol Syst 1:233–260

China Statistical Year book (2008) National Bureau of statistics of China. Beijing, China Statistics

Chua TT, Bronson KF, Booker JD, Keeling JW, Mosier AR, Bordovsky JP, Segarra E (2003) In-season nitrogen status sensing in irrigated cotton. Soil Sci Soc Am J 67:1428–1438

Ciompi S, Gentili E, Guidi L, Soldatini GF (1996) The effect of nitrogen deficiency on leaf gas exchange and chlorophyll fluorescence parameters in sunflower. Plant Sci 118:177–184

Clapp CE, Allmaras RR, Layese MF, Linden DR, Dowdy RH (2000) Soil organic carbon and 13 C abundance as related to tillage crop residue and nitrogen fertilization under continuous corn management in Minnesota. Soil Tillage Res 55:127–142

Constable GA, Rochester IJ (1988) Nitrogen application to cotton on clay soil timing and soil testing. Agron J 80:498–502

Coyne MS (2008) Biological denitrification 1. Nitrogen in Agricultural Systems 49:201

Dabney SM, Delgado JA, Reeves DW (2001) Using winter cover crops to improve soil and water quality. Communications in Soil Sci and Plant Analysis 32:1221–1250

Dai J, Dong H (2014) Intensive cotton farming technologies in China: achievements, challenges and countermeasures. Field Crop Res 155: 99–110

Daniel JB, Abaye AO, Alley MM, Adcock CW, Maitland JC (1999) Winter annual cover crops in a Virginia no-till cotton production system: II. Cover crop and tillage effects on soil moisture cotton yield and cotton quality. J Cotton Sci 3:84–91

Davidonis GH, Johnson AS, Landivar JA, Fernandez CJ (2004) Cotton fiber quality is related to boll location and planting date. Agron J 96: 42–47

Dong H, Zhang D, Tang W, Li W, Li Z (2005) Effects of planting system, plant density and flower removal on yield and quality of hybrid seed in cotton. Field Crop Res 93:74–84

Elberhar MW, Tupper GR (1988) Evaluation of deep band placement of nitrogen for cotton production. Soil Management Plt Ntr conf, Beltwide Cotton Production Res Conf New Orleans:501–504

Fahad S, Hussain S, Chauhan BS, Saud S, Wu C, Hassan S, Huang J (2015) Weed growth and crop yield loss in wheat as influenced by row spacing and weed emergence times. Crop Prot 71:101–108

Farooq M, Flower KC, Jabran K, Wahid A, Siddique KH (2011) Crop yield and weed management in rain fed conservation agriculture. Soil Tillage Res 117:172–183

Feng Y, Motta AC, Reeves DW, Burmester CH, Van Santen E, Osborne JA (2003) Soil microbial communities under conventional-till and no-till continuous cotton systems. Soil Biol Biochem 35:1693–1703

Fernáandez CJ, McInnes KJ, Cothren JT (1996) Water status and leaf area production in water and nitrogen-stressed cotton. Crop Sci 36:1224–1233

Ferreras LA, Costa JL, Garcia FO, Pecorari C (2000) Effect of no-tillage on some soil physical properties of a structural degraded Petrocalcic Paleudoll of the southern "Pampa" of Argentina. Soil and Tillage Res 54:31–39

Fritschi FB, Bruce AR, Travis RL, Rains DW, Hutmacher RB (2003) Response of irrigated Acala and pima cotton to nitrogen fertilization. Agron J 95:133–146

Gerik TJ, Oosterhuis DM, Torbert HA (1998) Managing cotton nitrogen supply. Adv Agron 64:115–147

Gilley JE (1995) Tillage effects on infiltration surface storage and over-land flow farming for a better environment: a white paper. Soil and Water Conserv Soc Ankeny IA, 46–47

Grant RF, Pattey E, Goddard TW, Kryzanowski LM, Puurveen H (2006) Modeling the effects of fertilizer application rate on nitrous oxide emissions. Soil Sci Soc Am J 70:235–248

Gregorich EG, Drury CF, Baldock JA (2001) Changes in soil carbon under long-term maize in monoculture and legume-based rotation. Can J Soil Sci 81:21–31

Guo Y, Ma X, Yang T, Niu X, Wang B, Xu Y, Liu N (2010) Effect of using top nitrogen fertilizer on abscission rate of cotton buds and bolls. Xingjiang Agric Sci 47:180–183

Halvorson AD, Wienhold BJ, Black AL (2002) Tillage nitrogen and cropping system effects on soil carbon sequestration. Soil Sci Soc Am J 66:906–912

Hargrove WL (1986) Winter legumes as a nitrogen source for no-till grain sorghum. Agron J 78:70–74

Harrison R, Webb J (2001) A review of the effect of N fertilizer type on gaseous emissions. Adv Agron 73:65–108

Hicks SK, Wendt CW, Gannaway JR, Baker RB (1989) Allelopathic effects of wheat straw on cotton germination, emergence, and yield. Crop Sci 29(4):1057–1061

Hobbs PR, Sayre K, Gupta R (2008) The role of conservation agriculture in sustainable agriculture. Philosophical Transactions of the Royal Society, Biological Sciences 363:543–555

Hou ZN, Li PF, Li BG, Gong J, Wang YN (2007) Effects of fertigation scheme on N uptake and N use efficiency in cotton. Plant Soil 290: 115–126

Howard DD, Gwathmey CO, Essington ME, Roberts RK, Mullen MD (2001) Nitrogen fertilization of no-till cotton on loess-derived soils. Agron J 93:157–163

Hultgreen G, Leduc P (2003) The effect of nitrogen fertilizer placement formulation timing and rate on greenhouse gas emissions and agronomic performance. Final Report Project No 5300G, ADF No 19990028, Saskatchewan Department of Agriculture and Food, Regina, SK

Hulugallc NR (2000) Carbon sequestration in irrigated vertisols under cotton based farming systems. Communications in Soil Sci and Plant Analysis 31:645–654

Hutchinson RL, Breitenbeck GA, Brown RA, Thomas WJ (1995) Winter cover crop effects on nitrogen fertilization requirements of no-till and conventional-tillage cotton. Conservation-tillage systems for cotton: a review of research and demonstration results from across the Cotton Belt, Arkansas. Agric Exp Stn:73–76

Ishaq M, Ibrahim M, Lal R (2001) Tillage effect on nutrient uptake by wheat and cotton as influenced by fertilizer rate. Soil and Tillage Res 62:41–53

Jaynes DB, Colvin TS, Karlen DL, Cambardella CA, Meek DW (2001) Nitrate loss in subsurface drainage as affected by nitrogen fertilizer rate. J Environ Qual 30:1305–1314

Karlen DL, Andrews SS, Doran JW (2001) Soil quality: current concepts and applications. Adv Agron 74:1–40

Khan IA, Ali A, Zubair M, Khan IA (2001) Mode of gene action controlling seed cotton yield and various components in Gossypium hirsutum L. Pak J Agric Sci 38:19–21

Koch B, Khosla R, Frasier WM, Westfall DG, Inman D (2004) Economic feasibility of variable-rate nitrogen application utilizing site-specific management zones. Agron J 96:1572–1580

Kumbhar AM, Buriro UA, Junejo S, Oad FC (2008) Impact of different nitrogen levels on cotton growth, yield and N-uptake planted in legume rotation. Pak J Bot 40:767–778

Lal R (2003) Global potential of soil carbon sequestration to mitigate the greenhouse effect. Critical Reviews in Plant Sci 22:151–184

Lal R, Kimble JM (1997) Conservation tillage for carbon sequestration. Nutri Cycl Agroecosyst 49:243–253

Larson JA, Jaenicke EC, Roberts RK, Tyler DD (2001a) Risk effects of alternative winter cover crop tillage and nitrogen fertilization systems in cotton production. J Agric and Appl Econ 33:445–458

Larson JA, Roberts RK, Jaenicke EC, Tyler DD (2001b) Profit-maximizing nitrogen fertilization rates for alternative tillage and winter cover systems. J Cotton Sci 5:156–168

Lindstrom MJ, Onstad CA (1984) Influence of tillage systems on soil physical parameters and infiltration after planting. J. Soil and Water Conserv 39:149–152

Liu C, Zheng X, Zhou Z, Han S, Wang Y, Wang K, Yang Z (2010) Nitrous oxide and nitric oxide emissions from an irrigated cotton field in Northern China. Plant Soil 332:123–134

Locke MA, Reddy KN, Zablotowicz RM (2002) Weed management in conservation crop production systems. Weed Biol and manage 2: 123–132

Lokhande S, Reddy KR (2015) Cotton reproductive and fiber quality responses to nitrogen nutrition. Int J Plant Prod 9:191–210

Lu C, Zhang J, Zhang Q, Li L, Kuang T (2001) Modification of photosystem II photochemistry in nitrogen deficient maize and wheat plants. J Plant Physiol 158:1423–1430

Ludwig J, Meixner FX, Vogel B, Förstner J (2001) Soil-air exchange of nitric oxide: an overview of processes, environmental factors and modeling study. Biogeochemistry 52:225–257

Mahmood T, Ali R, Iqbal J, Robab U (2008) Nitrous oxide emission from an irrigated cotton field under semiarid subtropical conditions. Biol Fertil Soils 44:773–781

Malhi SS, Lemke R, Wang ZH, Chhabra BS (2006) Tillage nitrogen and crop residue effects on crop yield nutrient uptake soil quality and greenhouse gas emissions. Soil and Tillage Res 90:171–183

Maraseni TN, Cockfield G, Maroulis J (2010) An assessment of greenhouse gas emissions: implications for the Australian cotton industry. J Agric Sci 148:501–510

Marschner H (2001) Marschner's mineral nutrition of higher plants. Academic Press

McConkey BG, Liang BC, Campbell CA, Curtin D, Moulin A, Brandt SA, Lafond GP (2003) Crop rotation and tillage impact on carbon sequestration in Canadian prairie soils. Soil and Tillage Res 74:81–90

McConnell JS, Baker WH, Miller DM, Frizzell BS, Varvil JJ (1993) Nitrogen fertilization of cotton cultivars of differing maturity. Agron J 85:1151–1156

Mokhele B, Zhan X, Yang G, Zhang X (2012) Review: nitrogen assimilation in crop plants and its affecting factors. Can. J. Plant Sci 92: 399–405

Mueller DH, Wendt RC, Daniel TC (1984) Phosphorus losses as affected by tillage and manure application. Soil Sci Soc Am J 48:901–905

Nadeem MA, Ali A, Tahir M, Naeem M, Chadhar AR, Ahmad S (2010) Effect of nitrogen levels and plant spacing on growth and yield of cotton. Pak J Life Soc Sci 8:121–124

Norton ER, Silvertooth JC (2007) Evaluation of added nitrogen interaction effects on recovery efficiency in irrigated cotton. Soil Sci 172: 983–991

Nyakatawa EZ, Reddy KC, Mays DA (2000) Tillage, cover cropping and poultry litter effects on cotton: II. Growth and yield parameters. Agron J 92:1000–1007

Nyakatawa EZ, Reddy KC (2000) Tillage cover cropping and poultry litter effects on cotton: I. Germination and seedling growth. Agron J 92:992–999

Legg OJ, Meisinger J (1982) Soil nitrogen budgets. Nitrogen in agric soils:503–566

Paul EA (2014) Soil microbiology, ecology, and biochemistry. Academic Press

Paxton KW, Boquet DJ, Hutchinson RL (2001) An economic analysis of best management practice adoption by Louisiana cotton producers. Proceedings of the Beltwide Cotton Conf Anaheim, In, pp. 193–195

Pettigrew WT, Heitholt JJ, Meredith WR (1996) Genotypic interactions with potassium and nitrogen in cotton of varied maturity. Agron J 88:89–93

Pettigrew WT, Jones MA (2001) Cotton growth under no-till production in the lower Mississippi river valley alluvial flood plain. Agron J 93: 1398–1404

Potter KN, Torbert HA, Jones OR, Matocha JE, Morrison JE, Unger PW (1998) Distribution and amount of soil organic carbon in long-term management systems in Texas. Soil and Tillage Res 47:309–321

Qiu Y, Wang Y, Xie Z (2014) Long-term gravel–sand mulch affects soil physicochemical properties microbial biomass and enzyme activities in the semi-arid loess plateau of North-Western China. Acta Agric Scand Section B-Soil and Plant Sci 64:294–303

Radin JW, Boyer JS (1982) Control of leaf expansion by nitrogen nutrition in sunflower plants role of hydraulic conductivity and turgor. Plant Physio 69:771–775

Read JJ, Reddy KR, Jenkins JN (2006) Yield and fiber quality of upland cotton as influenced by nitrogen and potassium nutrition. Eur J Agron 24:282–290

Reddy AR, Reddy KR, Padjung R, Hodges HF (1996) Nitrogen nutrition and photosynthesis in leaves of pima cotton. J Plant Nutr 19:755–770

Reddy KR, Hodges HF, McKinion JM (1997) Crop modeling and applications: a cotton example. Adv Agron:225–290

Reddy KR, Koti S, Davidonis GH, Reddy VR (2004) Interactive effects of carbon dioxide and nitrogen nutrition on cotton growth development yield and fiber quality. Agron J 96:1148–1157

Reicosky DC, Dugas WA, Torbert HA (1997) Tillage-induced soil carbon dioxide loss from different cropping systems. Soil and Tillage Res 41:105–118

Roberts I, Schierhout G, Alderson P (1998) Absence of evidence for the effectiveness of five interventions routinely used in the intensive care management of severe head injury: a systematic review. J Neurol Neurosurgery and Psychiatry 65:729–733

Rochester I, Constable G, Saffigna P (1996) Effective nitrification inhibitors may improve fertilizer recovery in irrigated cotton. Biol Fertil Soils 23:1–6

Rochester IJ (2003) Estimating nitrous oxide emissions from flood-irrigated alkaline grey clays. Soil Res 41:197–206

Sainju UM, Singh BP (2001) Tillage cover crop and kill-planting date effects on corn yield and soil nitrogen. Agron J 93:878–886

Sainju UM, Singh BP, Whitehead WF (2002) Long-term effects of tillage, cover crops and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil and Tillage Res 63:167–179

Sainju UM, Singh BP, Whitehead WF (2005) Tillage cover crops and nitrogen fertilization effects on cotton and sorghum root biomass, carbon and nitrogen. Agron J 97:1279–1290

Sainju UM, Whitehead WF, Singh BP, Wang S (2006) Tillage cover crops and nitrogen fertilization effects on soil nitrogen and cotton and sorghum yields. Eur J Agron 25:372–382

Saleem MF, Bilal MF, Awais M, Shahid MQ, Anjum SA (2010) Effect of nitrogen on seed cotton yield and fiber qualities of cotton (Gossypium hirsutum L.) cultivars. The Journal of Animal & Plant Sciences 20(1):23–27

Scheer C, Wassmann R, Kienzler K, Ibragimov N, Eschanov R (2008b) Nitrous oxide emissions from fertilized, irrigated cotton (*Gossypium hirsutum* L.) in the Aral Sea Basin, Uzbekistan: influence of nitrogen applications and irrigation practices. Soil Biol Biochem 40:290–301

Scheer C, Wassmann R, Kienzler K, Ibragimov N, Lamers JPA, Martius C (2008a) Methane and nitrous oxide fluxes in annual and perennial land use systems of the irrigated areas in the Aral Sea Basin. Glob Chang Biol 14:2454–2468

Schertz DL, Kemper WD (1994) Report on field review of no-till cotton. USDA ARS NRCS Auburn Univ, Alabama, Huntsville AL

Schimel JP, Bilbrough C, Welker JM (2004) Increased snow depth affects microbial activity and nitrogen mineralization in two Arctic tundra communities. Soil Biol and Biochemis 36:217–227

Schwab EB, Reeves DW, Burmester CH, Raper RL (2002) Conservation tillage systems for cotton in the Tennessee Valley. Soil Sci Soc Am J 66:569–577

Shaver TM, Peterson GA, Ahuja LR, Westfall DG, Sherrod LA, Dunn G (2002) Surface soil physical properties after twelve years of dry land no-till management. Soil Sci Soc Am J 66:1296–1303

Shiraiwa T, Sinclair TR (1993) Distribution of nitrogen among leaves in soybean canopies. Crop Sci 33:804–808

Skiba U, Smith KA (2000) The control of nitrous oxide emissions from agricultural and natural soils. Chemosphere-Global Change Sci 2:379–386

Smart JR, Bradford JM (1999) Conservation tillage corn production for a semiarid subtropical environment. Agron J 91:116–121

Sowers KE, Pan WL, Miller BC, Smith JL (1994) Nitrogen use efficiency of split nitrogen applications in soft white winter wheat. Agron J 86:942–948

Stute JK, Posner JL (1995) Synchrony between legume nitrogen release and corn demand in the upper Midwest. Agron J 87:1063–1069

Sui N, Zhou Z, Yu C, Liu R, Yang C, Zhang F, Meng Y (2015) Yield and potassium use efficiency of cotton with wheat straw incorporation and potassium fertilization on soils with various conditions in the wheat–cotton rotation system. Field Crop Res 172:132–144

Sweeney DW, Moyer JL (2004) In-season nitrogen uptake by grain sorghum following legume green manures in conservation tillage systems. Agron J 96:510–515

Tang HY, Yang GZ, Zhang XL, Siddique K (2012) Improvement of fertilizer N recovery by allocating more N for later application in cotton (Gossypium hirsutum L.). International Journal of Basic and Applied Sciences 12:32–37

Tenuta EG, Beauchamp M (2003) Nitrous oxide production from granular nitrogen fertilizers applied to a silt loam soil. Can J Soil Sci 83:521–532

Triplett GB, Dabney SM, Siefker JH (1996) Tillage systems for cotton on silty upland soils. Agron J 88:507–512

Van Den Bossche A, De B, De NS, Hofman G (2009) Effect of tillage intensity on N mineralization of different crop residues in a temperate climate. Soil and Tillage Res 103:316–324

Veiga MD, Reinert DJ, Reichert JM, Kaiser DR (2008) Short and long-term effects of tillage systems and nutrient sources on soil physical properties of a southern Brazilian Hapludox. Rev Brasil de Ciência do Solo 32:1437–1446

Velthof GL, Kuikman PJ, Enema O (2003) Nitrous oxide emission from animal manures applied to soil under controlled conditions. Biol Fertil Soils 37:221–230

Venterea RT, Burger M, Spokas KA (2005) Nitrogen oxide and methane emissions under varying tillage and fertilizer management. J Environ Qual 34:1467–1477

Venterea RT, Stanenas AJ (2008) Profile analysis and modeling of reduced tillage effects on soil nitrous oxide flux. J Environ Qual 37:1360–1367

Wang L, Zhu J, Yang T, Wang B, Chen B, Liu H, Xu Y, Ma X, Zhao D (2010) Effects of using strategy of N fertilizer on dry matter accumulation and yield component of cotton. Xingjiang Agri Sci 47:1952–1957

Yang G, Tang H, Nie Y, Zhang X (2011) Responses of cotton growth, yield, and biomass to nitrogen split application ratio. Eur J Agron 35:164–170

Yang G, Tang H, Tong J, Nie Y, Zhang X (2012) Effect of fertilization frequency on cotton yield and biomass accumulation. Field Crop Res 125:161–166

Yang G, Zhou X, Li C, Nie Y, Zhang X (2013) Cotton stubble mulching helps in the yield improvement of subsequent winter canola (Brassica napus L.) crop. Ind Crop Prod 50:190–196

Yoo KH, Touchton JT, Walker RH (1988) Runoff sediment and nutrient losses from various tillage systems of cotton. Soil and Tillage Res 12:13–24

Zhang L, Spiertz JHJ, Li Z, van B (2008) Nitrogen economy in relay intercropping systems of wheat and cotton. Plant Soil 303:55–68

Zhao D, Oosterhuis DM (2000) Pix plus and mepiquat chloride effects on physiology, growth, and yield of field-grown cotton. J Plant Growth Regul 19(4):415–422

Zhao D, Reddy KR, Kakani VG, Read JJ, Carter GA (2003) Corn (Zea mays L.) growth, leaf pigment concentration, photosynthesis and leaf hyperspectral reflectance properties as affected by nitrogen supply. Plant Soil 257:205–218

Zheng X, Wang M, Wang Y, Shen R, Gou J, Li J, Jin J, Li L (2000) Impacts of soil moisture on nitrous oxide emission from croplands: a case study on the rice-based agro-ecosystem in Southeast China. Chemosphere-Global Change Sci 2:207–224