

Effect of Tillage on Soil Nitrogen; A Review

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Abstract— Most farmers think that soil tillage activity is still one important part of efforts to increase crop production. But some of them have understood that reduced or no tillage (NT), in addition to saving money and time, not reducing crop yields even can also conserve and improve soil productivity. Several experiments have proven the advantages of NT compared with conventional tillage (CT). Without tillage practices in the long run have a good contribution to the total nitrogen content in the top soil. N mineralization levels were also higher in NT than under conventional tillage. Meanwhile to reduce emissions of N which indicated higher under NT than in CT is to avoid the practice of monoculture cropping systems, and the inclusion of legumes into cropping systems.

Keywords— No-tillage, conventional tillage, soil nitrogen.

I. INTRODUCTION

For many decades, prescriptions have been written that assumed the necessity of tillage to active economic crop production. Although soil degradation processes resulting from tillage of the surface soil are operative in all climate and soil region, the effects are seen more quickly in tropic [14], [16].

In general, there are two forms of soil tillage i.e. conventional tillage and conservation tillage. Conventional tillage is common tillage where surface soil is cultivated once or twice using implements such hoe, plow, disk, chisels, harrows, etc., while conservation tillage is the reducing of soil tillage practices or no tillage (NT) at all. Reducing tillage system is becoming increasingly popular and shows potential for reducing soil degradation. However, there is concern that over time of NT may lead to stratification of nutrients [29], [25].

Tillage management, due to changes in soil mixing may also affect distribution of the more mobile nutrients, such as NO₃-N and SO₄-S, soil water content, soil porosity, and organic matter break down. Fertilization tends to generate NO₃ leaching problems when applications are in excess of plant uptake [11], [24]. No-tilled soils present higher infiltration rate than conventional tillage [2], [4], [7]. Soil water leachates contain higher NO₃ concentrations in conventional tillage than in no-tillage production system [19], [11].

II. SOURCES AND FORMS OF NITROGEN IN THE SOIL

A. Sources of soil nitrogen

Reference [10] stated, the ultimate source of the nitrogen used by plants is the inert gas N₂, which constitutes about 78 % of the earth's atmosphere. The primary pathways by which nitrogen is converted to forms usable by higher plants are a) fixation by rhizobia and other microorganisms that live symbiotically on the roots of legumes and certain nonleguminous plants, b) fixation by free-living soil microorganisms and perhaps by organism living on the leaves of tropical plants, c) fixation as one of the oxides of nitrogen by atmospheric electrical discharges, and d) fixation as ammonia, NO₃⁻, or CN₂⁻ by any of the various industrial processes for the manufacture of synthetic nitrogen fertilizers.

B. Forms of Soil Nitrogen

The total nitrogen content of soils ranges from less than 0.02 % in subsoil to more than 2.5 % in peats. The nitrogen present in soil can generally be classed as inorganic or organic and 95 % or more of the nitrogen in surface soil usually occurs in organic form [10], [26]. The inorganic forms of soil nitrogen include ammonium (NH₄⁺), nitrate (NO₃⁻), nitrous oxide (N₂O), nitric oxide (NO), and elemental nitrogen (N₂). From the standpoint of soil fertility, the NH₄⁺, NO₂⁻ and NO₃⁻ forms are of greatest important. While the organic forms of soil nitrogen occur as consolidated amino acid or proteins, free amino acids, amino sugar and other complex, generally unidentified compound [10].

III. TILLAGE EFFECTS ON SOIL NITROGEN

A. N-dynamic

An 11 to 15 year study was found that the total soil organic carbon (SOC) and N content were greater under NT than under conventional mechanical tillage [5], [12]. The Effect were apparent in the 0 – 7.5 cm and 7.5 – 15 cm depth such data in Table 1. Another study [1], [9] also showed that C and total N in the top of soil (depth 0 – 15 cm) was higher under NT and reduced tillage than under CT. The entire document should be in Times New Roman or Times font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes. Recommended font sizes are shown in Table 1.

TABLE I
EFFECT OF CROP ROTATION AND TILLAGE ON TOTAL N AMOUNT IN THE 0 – 7.5 CM AND 7.5 - 15 CM DEPTH OF SCEPTER CLAY IN SOUTHWESTERN (1986-1994)

Soil Depth and Year	Total N			
	Continues Wheat		Fallow wheat	
	CT	NT	MT	NT
	-----ton/ha-----			
0 – 7,5 cm				
1986	1.25	1.43	1.22	1.36
1990	1.40	1.52	1.26	1.57
1994	1.40	1.66	1.27	1.51
Mean	1.35	1.54	1.25	1.48
Signif.of F ratio	Treatment **:year**			
LSD (P<.01)	0.13: 0.07			
7,5 – 15 cm				
1986	1.64	1.75	1.47	1.82
1990	1.30	1.26	1.32	1.48
1994	1.56	1.56	1.49	1.67
Mean	1.50	1.52	1.43	1.66
Signif.of F ratio	Treatment *:Year**			
LSD (P<.01)	0.17: 0.08			
0 – 15 cm				
1986	2.89	3.19	2.68	3.18
1990	2.69	2.78	2.58	3.05
1994	2.95	3.22	2.71	3.18
Mean	2.85	3.06	2.67	3.14
Signif.of F ratio	Treatment **:year**			
LSD (P<.01)	0.28: 0.14			

Source: Campbell et al., (1996).

B. N-mineralization

Reference [3] and [8] reported that the soil under NT had greater potential N mineralization than under CT. N mineralization in combination NT with crops such as wheat, sorghum and soybean had 45, 65 and 105 % was greater than in combination CT with the same commodity. The ratio of potential N mineralization to initial inorganic N content was 0.67, to 1.05 under CT but was 1.29 to 1.62 under NT. This indicates that soil subjected to long-term CT had more N in the inorganic form, which may have been subject to leaching and gaseous losses and less N in a mineralizable organic form [8].

Reference [3] and [28] showed nitrogen mineralization generally increase in the 0 to 0.05 m layer as intensity of tillage decreased in most comparisons. Under NT system, crop residue is made available to soil microorganism at a

slower rate for a longer duration, soil temperature are lower, the soil is more moist, and the soil is in a less oxidative condition [6], [13].

Reference [28] also reported that N-mineralization rate under the different tillage system were affected by the rate of N fertilization as well. N-mineralization rates were higher under no tillage than under minimum or conventional tillage at the two lower N rate (34 and 67 Kg N/ha), and higher under minimum and no tillage than under conventional tillage at the high N rate (101 kg/ha) (Table 2).

TABLE III
NITROGEN MINERALIZATION RATE FOR SOIL FROM 0 TO 0.05 M DEPTH AS A FUNCTION OF TILLAGE AND N RATE IN THE ANNUAL CROPPING SYSTEM

Tillage	N rate		
	34†	67	101
	Kg ha ⁻¹ wk ⁻¹		
Conventional	7.9 ± 0.8a‡	7.7 ± 0.8a	5.5 ± 0.8a
Minimum	8.6 ± 0.6a	7.8 ± 1.0a	7.3 ± 0.6b
No-tillage	14.1 ± 1.8b	11.0 ± 1.2b	7.9 ± 0.5b

† Kilogram per hectare

‡ LSD.05 = 1.6; value in a column followed by different letters are significantly different

Source: Reference [28]

C. N-leaching

The measurement results of nitrate leached from a conventional tillage and no till system (Table 3) was studied for 2 year as in [17].

TABLE III
COMPARISON OF THE NO₃-N IN THE SOIL WITH THAT IN THE SOIL SOLUTION BELOW THE ROOT ZONE

Treatment	NO ₃ -N	
	Soil 0 to 0.45 m May, June, July †	Soil solution avr. Of 1.2 and 1.5 m June, July, August
	mg kg ⁻¹	mg L ⁻¹
Corn (1990)		
No tillage (NT)	14 (56) ‡	9
Tillage (CT)	19 (77)	10
Wheat (1991)		
No tillage (NT)	4 (16)	4
Tillage (CT)	6 (24)	10

† Used different times to compensate for the time necessary for the soil solution to flow from the surface to the 1.2 to 1.5 m depth

‡ Estimated NO₃-N in the soil solution (soil NO₃-N x 4.03 [1.33 Mg m⁻³ bulk density and 0.33 m³ m⁻³ volumetric water content])

Source: Reference [17]

Table 3 shows both under corn and wheat, NO₃-N concentration leached to 1.2 to 1.5 m depth is higher in the CT system than NT system. Reference [9] reported higher concentration of NO₃-N under CT than under NT in the 15 – 30 cm and 30 – 60 cm depth after 4 year of tillage treatment. They also reported, leaching of NO₃-N to below root zone besides it is affected by tillage system it is also affected by soil texture.

Another experiment [20] using Lysimeters showed that leached NO₃-N under CT no fertilization (CT-NF) is approximately 4 mg NO₃-N L⁻¹ and under NT no

fertilization (NT-NF) is 2 mg NO₃-N L⁻¹. They also measured the distribution of extractable mineral N within the soil profile of CT and NT plots, with N fertilization (125 kg N/ha) (F) and no N (NF) applied (Fig. 1). As in [18] total leaching of NO₃-N in the NT system was significantly 46 and 33% lower than in the CN system during the first and second crop rotation cycle, respectively. Meanwhile reference [1] found that the NO₃-N concentration leaching from all tillage treatments was generally not significantly different, although in NT system the leached NO₃-N was less. The higher NO₃-N level in NT system may be due to release from organic matter residues retained near the soil surface with lack of tillage. Also residual N from fertilizer application may have been retained near the soil surface under the relatively dry condition during the study period.

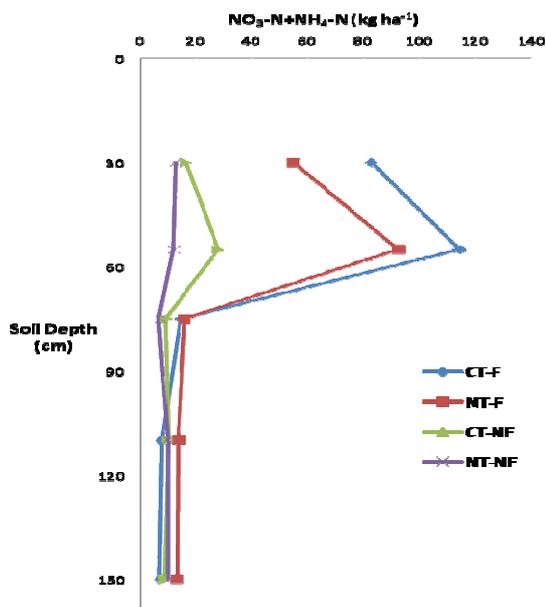


Fig. 1 Distribution of extractable N within the soil of CT and NT plots with N fertilization (125 kg N/ha) (F) and no fertilization (NF)
Source: Rasse and Smucker, (1999)

D. N-emission

According to reference [15], [22] N₂O emission fluxes from soil in NT system was greater than in CT system. It may be associated with an increase in soil moisture and temperature with NT and higher soil mineral N with fertilization. The rate of emission becomes greater as fertilizer N rate increase especially under monoculture corn fields [15] (Table 4). In soybean or alfalfa, increasing in emission with added N was generally small and not significant. The same result was found by another researcher [21] that nitrogen fertilization on corn increased emission from the soil by providing additional N. Inclusion of legumes into cropping system may be reduce and lower N₂O emission than under continues corn.

Measurement result of the NO, and N₂O emission from various type of fertilizer was anhydrous ammonia (AA), urea ammonium nitrate (UAN) and broadcast urea (BU) applied to soil under NT and CT showed the different result for different fertilizer [22]. The emission of N₂O was greater under CT when AA and BU applied, while under NT was

greater when UAN applied. The emission of NO was greater under NT when AA applied and contrary when BU and UAN applied (Fig 2).

TABLE IV
CUMULATIVE NITROUS OXIDE EMISSION LOSSES AS INFLUENCED BY ROTATION, TILLAGE SYSTEM AND NITROGEN FERTILIZER RATES IN 2 DIFFERENT SITES IN THE 1994 GROWING SEASONS

Treatments	N ₂ O emission (Kg N ha ⁻¹)		
	NT	CT	NT vs. CT
Location			
Ste. Rosalie (2) soil*	2.06	1.76	*
Ormstown soil*	3.52	2.21	*
Crop rotation			
CCCC**	5.43	2.12	**
SCSC*	5.28	2.42	**
CSAC	3.87	2.70	NS
SSSS	3.31	2.12	NS
CSCS	2.31	2.17	NS
SACS	1.91	1.70	NS
ACSA	1.91	2.16	NS

C = Corn, S = Soybean, A = Alfalfa. Rotation symbols refer to years 1991, 1992, 1993 and 1994

**significant at P = .05 and P = .01 respectively, NS = not significant
Source: Reference [15]

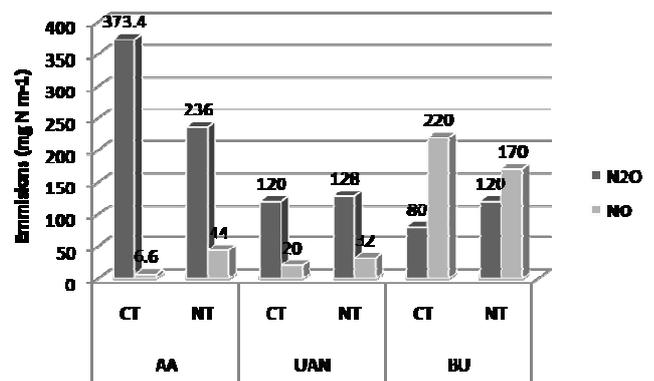


Fig. 2 Emission of NO and N₂O from the soil of NT and CT system treated by N fertilizer of anhydrous ammonia (AA), urea ammonium nitrate (UAN) and broadcast urea (BU) [22]

IV. CONCLUSIONS

Many experiments have proved that tillage system affect soil nitrogen dynamic significantly. Practicing no tillage (NT) in a long-term period gives good contribution on total soil nitrogen content in top soil. The N mineralization rate is also higher under NT than under conventional tillage (CT), however it was affected by the rate of N fertilization as well. The rate of mineralization is assumed to reduce the amount of N leached to the sub soil. The soil subjected to long-term CT have more N in the inorganic form which may have been subjected to leaching and gaseous losses and less N in a mineralizable organic form. The experiments have indicated the leached NO₃-N in layers below root zone was higher under CT.

The concrete data indicate that application of NT system in a soil management is an alternative method to conserve and improve soil nitrogen and soil quality as well. To reduce emissions of N which indicated higher under NT than in CT is to avoid the practice of monoculture cropping systems, and the inclusion of legumes into cropping systems.

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