Maize Yield, Plant Tissue and Residual Soil N as Affected by Nitrogen Management and Tillage Systems

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ABSTRACT

Tillage system and fertilizer management are needed to improve sustainable maize production. To investigate the impact of conventional tillage (CT) and no tillage (NT) system on nitrogen (N) application rates and their application at various growth stages (S) on maize production, experiments were conducted at Cereal Crops Research Institute Pirsabak, Nowshera (NWFP), Pakistan, during 2004 and 2005, respectively. Each experiment was consisted of two tillage systems; NT and CT, three levels of nitrogen (N) fertilizer i.e. (60,120 and 180 kg N ha^{-1}) and its application at various growth stages (S) i.e. full dose at sowing (S1), full dose at 5 leaves stage of the plant (S2), three equally split doses i.e. at sowing, 5 leaves and pre tasseling stage (S3), two equally split doses i.e. at sowing and 5 leaves (S4), two equally split doses i.e. at sowing and pre tasseling (S5) and two equally split doses i.e. at 5 leaves and pre tasseling (S6). Conventional Tillage resulted lower post harvest soil N. Likewise, CT improved grain yield and tissue N content. Higher grain yield was recorded with 120 kg N ha^{-1}. Similarly N applied at various growth stages significantly affected post harvest soil and tissue N content. A full dose of N when applied at 5 leaves stage resulted more accumulation of N by plant tissue. Significant interaction among tillage and N was observed for post harvest soil N. Grain yield increased linearly with increase in N level with CT while under NT 120 kg N ha^{-1} maximum grain yield was obtained. Interaction of N and its application at various growth stages were significant for grain yield and soil residual N. Interaction of N level and its application at various growth stages were significant for grain yield and post harvest soil N. With 60 kg N ha^{-1}, higher grain yield was recorded in interaction with S6, while in case of 120 and 180 kg N ha^{-1}, higher grain yield was recorded with S4 and S1, respectively. With 60 kg N ha^{-1}, higher post harvest soil N content was recorded at S3, while in case of 120 and 180 kg N ha^{-1}, higher post harvest soil N content was recorded with S2 and S3, respectively, while NT with 180 kg N ha^{-1} S5 produced the same. CT in interaction with 180 kg N ha^{-1} and S3 recorded maximum grain yield while NT with 120 kg N ha^{-1} and S6 produced maximum grain yield. It was concluded that CT in interaction with 120 kg N ha^{-1} and split application of N showed higher yield. Individually, CT, 120 kg N ha^{-1} and split application of N exhibited excellent performance as compared with their associated levels.

Key words: maize, tillage, nitrogen, yield, soil residual N, plant tissue N

INTRODUCTION

Tillage improves soil condition for crop production. Recently conservation tillage is emphasized for soil water conservation, fuel energy saving, and erosion control (Torbet *et al.*, 2001). Surface crop residues affect the availability of nitrogen to crop. The surface residue in no-till system may result in significant immobilization of surface-applied nitrogen. When nitrogen fertilizer is applied as urea, the nitrogen may also be lost by escaping as NH_3 gas into the atmosphere (Keller and Mengel, 1986). This loss is indirectly related to surface crop residues.

Tillage operation and soil disturbance generally can cause an increase in soil aeration, residue decomposition, organic N mineralization, and the availability of N for plant use (Dinnes *et al.*, 2002). In contrast, no-tillage system cause minimal soil disturbance and increase the buildup of surface residue, which may increase both N immobilization (Gilliam and Hoyt, 1987) and N losses from leaching and denitrification (Gilliam and Hoyt, 1987).

Soils in no-till systems are more efficient in water capacity (Brandt, 1992) and tend to be moist than the plowed soils. The crop residues accumulation due to lower mineralization rates (Rice and Smith, 1984) on soil surface reduces evaporation from soil. Alternatively, tillage promotes evaporation and dries out soil to the depth of tillage. Thus, no-till soils do not improve soil aeration and surface residue incorporation in to soil (Dinnes *et al.*, 2002).

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Soil moisture and temperature, which are greatly affected by tillage, also affect soil N dynamics (Torbet and Woods, 1992; Nadelhoffer *et al.*, 1991). The use of conservation tillage has been reported to increase short-term immobilization due to the slower plant decomposition process when tillage is limited (Gilliam and Hoyt, 1987; Wood and Edwards, 1992). Generally, in conservation tillage, fertilizer N rates have been increased as much as 25% to counter the adverse effect on yield from short term immobilization (Randall and Bandel, 1991). It has been hypothesized that application efficiency of fertilizer N can be enhanced by synchronizing fertilizer application with plant demands (Keeny, 1982). Fertilizer applied during peak plant N demand ensure greater N use efficiency due to limiting losses from the soil-plant system by leaching and denitrification (Keeny, 1982). Synchronization of N mineralization from crop residue, fertilizer N-application time, and subsequent crop demand for N can improve N use efficiency of crops grown in conservation tillage system (Reeves *et al.*, 1993). A beneficial tillage system for the soil with the integration of applied N fertilizer dynamics is needed. Objectives of the present study were to determine the impact of tillage system and nitrogen application rates on maize yield, plant tissue and residual soil N and to examine the impact f nitrogen application at various growth stages within these tillage systems on maize production.

MATERIALS AND METHODS

Experimental Site

Field experiments were conducted at Cereal Crops Research Institute Pirsabak, Nowshera, Pakistan for two consecutive years (2004 and 2005). The experimental site has a latitude of 32^o N, longitude 72^o E and altitude of 288 meter above sea level. The soil was sandy loam, moderately calcareous, having 0.034% N, 0.0029% P, 0.051% K, 0.028% total soluble salts and 0.34% organic matter with a pH of 7.7.

Tillage and Fertilizer Treatments

Experiment consisted of two tillage systems (NT and CT), three levels of N fertilizer (60,120 and 180 kg N ha^{-1}) and N application at six growth stages of crop (details given below). The experiments were conducted in Randomized Complete Block (RCB) design in a split plot arrangement having four replications. The combinations of tillage systems and N levels were allotted to main plots while application stages to sub plots. Each experiment was consisted of two tillage systems; NT and CT, three levels of nitrogen (N) fertilizer i.e. (60,120 and 180 kg N ha^{-1}) and its application at various growth stages (S) i.e. full dose at sowing (S1), full dose at 5 leaves stage of the plant (S2), three equally split doses i.e. at sowing, 5 leaves and pre tasseling stage (S3), two equally split doses i.e. at sowing and 5 leaves (S4), two equally split doses i.e. at sowing and pre tasseling (S5) and two equally split doses i.e. at 5 leaves and pre tasseling (S6).

Each sub plot was 5 m long and 4.5 m wide having 6 rows of 75 cm apart with plant to plant distance of 25cm. Conventional tillage (CT) was practiced by using common cultivator which tilled the soil to a depth of 30cm. No preparatory or post sowing tillage was carried out in no-till (NT) system. Planting was done by dibbling method in both the tillage systems. Maize variety Azam was planted on 17 and 19th June in 2004 and 2005, respectively. Details and combination of the treatments are as follow:

Agronomic Practices

A seed rate of 30 kg ha^{-1} was used for both tillage systems. The seed was treated with Confidor powder (Bayer Crop Science, Germany) @ 7g kg^{-1} before sowing to control the insect pests (whitefly, jassids, aphids and thrips) attack in the earlier stages of crop growth. Two seeds per hill were planted in each sub-plot. The seasonal and perennial weeds emerged in no-till plots were controlled by spraying round-up herbicides @ 2.47 L ha^{-1} two weeks earlier from sowing. After sowing, the whole experimental area was sprayed with Primextra gold (Syngenta, Switzerland) @ 2 L ha^{-1} for the control of seasonal weeds.

The full dose of recommended phosphatic fertilizer i.e. 30 kg P_2 O_5 was applied before planting during land preparation. The N application at various growth stages was applied by side dressing method.

A total of 6-8 irrigations were practiced during the crop period in both years. Granular insecticides Furadon (10%) (FMC, Pakistan) was applied twice @ 20 kg ha^{-1} to control stem borer. Thinning was done after complete emergence to adjust to one plant per hill.

Data Recorded

Data were recorded on grain yield (kg ha^{-1}, post harvest soil N (g kg^{-1}) and Tissue N content (g kg^{-1}). The grain yield of each sub plot was calculated after harvest by adjusting fresh ear weight to 150 g kg^{-1} grain moisture content (Carangal *et al.*, 1971) using the relationship: Grain yield= (100-M.C) × FEW × Shelling co-efficient / (100-15) Where, MC = Percent moisture in grain at harvest, FEW = Fresh Ear Weight (kg) at harvest, Shelling Co-efficient = Shelling %age / 100.

Soil and Plant Analysis

Total N in the soil and plant tissues was determined by the Kjeldahl method of Bremner and Mulvaney (1982). A known weight of oven dry soil (0.5 g) or plant materials (0.2 g) was digested for one hour in concentrated H_2SO_4 (ml) plus ¼ catalyst tablet. After cooling, the digest was made alkaline with 40% NaOH solution and the NH_3 distilled was collected in 10 ml boric acid contain mixed indicator. Total N was determined by titrating the distillate against 0.01 M HCl.

Boric mixed indicator solution was prepared by dissolving 20 g of boric acid in 980 ml distilled water and then adding 20 ml of mixed indication solution which was made up by dissolving 0.1 g bromocresol green and 0.07 g methyl red in 100 ml of 95% ethanol.

Statistical Analysis

The data recorded were analyzed statistically combined over years using analysis of variance techniques appropriate for randomized complete block design. Main and interaction effects were compared using LSD test at 0.05 level of probability, when the F-values were significant. (Steel and Torrie, 1980). A single d.f. (degree of freedom) Contrast Method involved the partitioning of sum of squares for overall treatment means to identify the significant component of these means. For this purpose, sets of orthogonal coefficient were used to calculate the single degree of freedom comparisons (Gomez and Gomez, 1982).

RESULTS AND DISCUSSION

Grain Yield

Tillage (T) and fertilizer nitrogen (N) significantly increased grain yield of maize (Table 2). The stages of N application (S) did not show any effect on grain yield. However, planned mean comparison detected that split application of N resulted in higher grain yield as compared to full dose of N at sowing or 5 leaves. The interaction among T x N, N x S and T x N x S were also significant for grain yield. Year as a source of variation also had significant effect on grain yield of maize.

Conventional tillage (CT) produced significantly higher grain yield as compared to no-tillage (NT). Grain yield increased with increase in N level from 60 kg ha^{-1} to 120 kg ha^{-1} but further increase in N level to 180 kg ha^{-1} declined grain yield of maize. Mean values of T x N interaction indicated that grain yield had a positive linear relationship with increasing levels of N in CT system while grain yield enhanced with increase in N level from 60 to 120 kg N ha^{-1}, but further increase in N to 180 kg ha^{-1} decreased grain yield of maize in NT system. The N x S interaction showed that grain yield mostly increased with increase in N level irrespective of N application stages. The interaction of tillage practices, nitrogen level and fertilizer application stages indicated that the highest grain yield was produced by 180 kg N ha^{-1} when applied in three splits under CT while NT was beneficial for grain yield when 120 kg N ha^{-1} was applied in two splits. Weather conditions varied and high rainfall occurred during summer 2005 as compared to summer 2004 (Table 1). Precipitation conditions varied and a heavy rain occurred in July and August (243.50 and 94.15 mm) of the experiment growing season in 2005 as compared to

Table 1. Monthly precipitation and temperature during the experimental seasons.

			Rainfall (mm)			
Years			**Months**			
	June	**July**	**August**	**September**	**October**	**November**
2004	**0.45**	**21.14**	**5.66**	**24.00**	**106.18**	**19.75**
2005	**74.68**	**243.50**	**94.15**	**7.50**	**0.00**	**0.00**
			Temperature (C^0)			
2004	**31.7**	**32.34**	**30.75**	**29.24**	**21.37**	**17.93**
2005	**32.33**	**31.11**	**29.30**	**28.60**	**19.40**	**17.46**

(21.14 and 5.66 mm) same months of 2004 (Table 1). This was followed by extremely low precipitation in the following months in 2005, while in 2004; the rain was frequent and evenly distributed. These variations resulted in wide differences in corn grain yield and other growth and yield related parameters. Fertilizer N runoff and leaching was suspected by the earlier heavy precipitation during 2005. No significant variation among monthly average air temperature within experimental seasons was recoded during 2004 and 2005 (Table 1). These variations resulted in wide differences in corn grain yield and other growth and yield related parameters. High corn production in 2004 might be due to frequent and uniform distribution of rainfall while low corn production in 2005 were attributed to the excess of rainfall during the growing season which causes runoff and leaching of N and ultimately N deficiency.

The lower grain yield with NT probably resulted from the slow early crop growth compared to the CT system (Halvorson *et al.*, 2006). Sims *et al.*, (1998) suggested that pre-plant tillage may be necessary to optimize grain yield and reported lower continuous corn yields with NT compared with CT. However, many researchers suggest that the delay in the early crop growth and development with NT had no detrimental effect on final crop yield (Mehdi*et al.*, 1999). Similarly, Beyaert *et al.*, 2002 reported that the effects of different tillage systems on early corn growth did not result in biological consequences sufficient to affect reproductive yield. Modifying the NT system by adopting zero tillage (ZT) system did not improve the growing conditions sufficiently for corn to produce significantly higher yields, nor did it cause a serious reduction in yield relative to CT. Kitur *et al*. (1984) argued that lower grain yield of maize might be due to greater N immobilization and NO_3 leaching in NT as compared to CT. Jones *et al.* (1969) noted increase soil water in the root zone as the primary factor causing plant growth and yield increase with CT. Improved grain yield in CT system has also been reported by Halvorson *et al.*, 2006. Similarly, Pederson and Lauer, (2003) noted 5% lower corn yield while Hussain *et al.* (1999); reported 35% lower grain yield in NT than CT. The optimum N rate (needed to achieve maximum yield) is influenced by factors including soil type, tillage, irrigation, fertilizer timing and method, and crop yield potential. These factors, as well as the interaction of these factors, will vary greatly from one location to another in a given geographic region (Gehl *et al.,* 2005). Results indicate that yield potential is more strongly influenced by previous crop, fertilizer N rate, and N placement method than tillage system (Kelley and Sweeney, 2005). Maize begins to rapidly taken up N during the middle vegetative growth period with the higher rate of N uptake occurring near silk

Table 2. Grain yield of maize as affected by levels of N its application at various plant growth stages under no tillage (NT) and conventional tillage (CT) systems over the two year.

Tillage	Stages	N (g ha^{-1})			Mean
		60	120	180	
			T x N x S		T x S
			Mg ha^{-1}		
NT	S1	4.57	6.10	6.70	5.79
	S2	5.08	6.56	5.39	5.67
	S3	5.16	6.11	6.11	5.79
	S4	4.88	6.69	6.02	5.86
	S5	5.43	6.49	6.00	5.97
	S6	5.93	6.77	6.37	6.36
CT	S1	6.47	7.06	7.12	6.88
	S2	6.57	6.75	6.77	6.70
	S3	6.44	7.05	7.56	7.02
	S4	7.06	7.02	7.21	7.10
	S5	6.68	7.13	7.04	6.95
	S6	7.00	6.90	6.96	6.95
			T x N		T
NT		5.17	6.45	6.10	5.91 b
CT		6.70	6.99	7.11	6.93 a
			N x S		S
	S1	5.52	6.58	6.91	6.33
	S2	5.83	6.65	6.08	6.19
	S3	5.80	6.58	6.83	6.41
	S4	5.97	6.86	6.61	6.48
	S5	6.06	6.81	6.52	6.46
	S6	6.46	6.84	6.67	6.66
	Mean	5.94 c	6.72 a	6.60 b	
Planned mean comparison for stages of N application with statistical significance					
Contrast			1st mean	2nd mean	Sign.
Full vs. Split			6.26	6.64	**
Full early vs. Full mid			6.33	6.19	NS
3 Split vs 2 Split			6.41	6.72	NS
Early+mid vs.(Early+late)+(Mid+late)			6.48	6.84	NS
Early+late vs. Mid+late			7.02	6.66	NS
Year 1 vs. Year 2			7.41	5.43	**

$LSD_{(0.05)}$ for Tillage = 0.13, Nitrogen = 0.16, Stage = NS, Interactions T x N = **, T x S = NS, N x S = **, T x N x S = * Means followed by different letters of the various categories are significantly different at 5% level of probability using LSD test. NS = Not significant,* Significant at 5% level of probability. **= Significant at 1% level of probability using LSD test.

(Hanway,1963). Time of N application studies have been reported extensively in the literature.

The general conclusions among researchers are that N application should be synchronized with the crop demand i.e., side-dressed several weeks after corn emergence (Fox *et al.,* 1986). Plant uptake of fertilizer N is more efficient when applied just before maximum plant need, subject to lower N losses through denitrification or leaching, or lower N immobilization in organic forms (Wells and Bitzer, 1984). When fertilizer was applied at six leaf stage to the maize, N uptake and grain yield were increased compared to fertilization at planting (Rozas *et al.*, 1999). Higher N uptake and grain yield with fertilization at six leaf stage have been reported by Wells *et al.*, (1992). Likewise, Lathwell *et al.* (1970) have shown increased grain yields and more efficient use of fertilizer N by corn when N application was delayed until several weeks post emergence rather than applied before planting. Fertilizer N was utilized more effectively, resulting in increased yields when applied 5 weeks after planting rather than at planting (Reeves and Touchton, 1986). These results agree with those of Russelle *et al.* (1983), who reported increased effectiveness of N from delayed applications. Improved efficiency with delayed N application is consistent with the concept of providing N at the time of maximum uptake, which occurs in a two to three weeks period just before silking (Russelle *et al.*, 1983) or slightly earlier (Hanway, 1962). This increased efficiency is the result of a combination of plant and soil factors.

Grain yield increases with increasing level of N (Schmidt *et al.*, 2002). Gehl *et al.* (2005) achieved maximum grain yield with 185 kg N ha^{-1} at all sites but reported that in most instances 125 kg N ha^{-1} was sufficient to achieve maximum grain yield. A possible means to increase the fertilizer N efficiency is to split-apply the fertilizer N. The side dress application, N fertilization several weeks after corn emergence, has maximized the efficiency of fertilizer N in most situations (Piekielek ad Fox, 1992). Also, the presence of plants at the time of side dressing application reduces NH_3 volatilization loss by shading and absorption of some of the evolved NH_3 (Harper *et al*., 1983). Split application of N results in greater N efficiency and recovery by the corn plants (Guillard *et al.*, 1999). Likewise, Bundy *et al*. (1994) noted greater N efficiency when applied just before the period of rapid N uptake by corn and a shorter exposure time to leaching and de-nitrification. Similarly, Rozas *et al*. (2004) reported that N application at later stage is better than at sowing because of denitrification: When N was applied at planting, cumulative de-nitrification losses were greater than those observed for fertilization at the six leaf stage. However, Jokela and Randall, 1989 reported that delaying N application from planting to 8 leaf stage did not increase grain or total DM production or fertilizer N use efficiency.

Post Harvest Soil Nitrogen Content

Data collected during 2004 and 2005 were combined and are presented in Table 3. Significantly more post harvest soil N (0.398) was observed during 2004 as compared to 2005 (0.384).

Various tillage practices, nitrogen levels, the interaction of tillage practices & nitrogen levels, stages of fertilizer application and their interactions with tillage practices & nitrogen levels affected soil N contents after harvest. Tillage practices had significant impact on post harvest soil N. Higher residual soil N accumulation was noted in no-tillage (NT) system (0.411 g kg^{-1}) compared to conventional tillage (CT) (0.371 g N kg^{-1}). Among the nitrogen levels, 60 and 180 kg N ha^{-1} resulted in higher post harvest soil N content (0.410 and 0.391 g kg^{-1} respectively) while 120 kg N ha^{-1} were observed 0.037 g kg^{-1} post harvest soil N content. Significant differences were observed among various application stages of N fertilizer. Significant impact of sole application at sowing was observed as compared to sole application at 5 leaves stage for residual soil N. Post harvest soil N (0.410 g kg^{-1}) seems to be enhanced when N was applied as full dose (sole) at sowing compared to full application at 5 leaves stage (0.379 g kg^{-1}). Similarly higher post harvest soil N content (0.437 g kg^{-1}) was recorded when fertilizer was applied in three split doses compared to (0.373 g kg^{-1}) two split doses. The mean comparison within split applications, post harvest soil N seems to be increased when nitrogen was applied at mid and late stage compared to early application. The interaction of tillage and nitrogen level showed significant effect on percent post harvest soil N content. As the nitrogen rate increased, the post harvest soil N increased and reached to the higher extent under NT system. While in CT, more residual soil N contents were observed with 60 kg N ha^{-1} followed with 180 and 120 kg N ha^{-1} respectively.

The interaction between nitrogen level and fertilizer application stages was also significant. The significantly highest amount of 0.473 g kg^{-1} post harvest soil N content was produced with 60 kg N ha^{-1} and three splits of fertilizer N. It was followed by 0.444 g kg^{-1} soil N with 180 kg N ha^{-1} and three splits of fertilizer N application. Significantly lesser amount of 0.311 g kg^{-1} soil N remained from 120 kg N ha^{-1} when applied in two splits i.e. at sowing and pre tasselling stages.

The interaction of tillage (CT or NT) and fertilizer application at various growth stages also showed significant effect on post harvest soil N content. The highest amount of 0.496 g kg^{-1} soil N was recorded under NT when received in three split doses. It was followed by 0.442 g kg^{-1} soil N with two splits i.e. at 5 leaves and pre tasselling. Significantly lesser amount of 0.321 g kg^{-1} post harvest soil N content was recorded from CT and two equally split doses i.e. at sowing and 5 leaves stage.

Table 3. Post harvest soil N of maize as affected by levels of N and its application at various plant growth stages under no tillage (NT) and conventional tillage (CT) systems over the two years.

Tillage	Stages	N (kg ha^{-1})			Mean
		60	120	180	
			T x N x S		T x S
			g kg^{-1}		
NT	S1	0.361	0.465	0.320	0.382
	S2	0.453	0.436	0.321	0.403
	S3	0.508	0.444	0.536	0.496
	S4	0.341	0.435	0.368	0.381
	S5	0.321	0.326	0.430	0.359
	S6	0.369	0.431	0.525	0.442
CT	S1	0.523	0.293	0.501	0.439
	S2	0.305	0.356	0.401	0.354
	S3	0.438	0.345	0.353	0.378
	S4	0.325	0.343	0.295	0.321
	S5	0.465	0.295	0.334	0.365
	S6	0.518	0.281	0.308	0.369
			T x N		T
NT		0.392	0.423	0.417	0.411a
CT		0.429	0.319	0.365	0.371b
			N x S		S
	S1	0.442	0.379	0.411	0.410b
	S2	0.379	0.396	0.361	0.379c
	S3	0.473	0.394	0.444	0.437a
	S4	0.333	0.389	0.331	0.351e
	S5	0.393	0.311	0.382	0.362d
	S6	0.443	0.356	0.416	0.405b
	Mean	0.410a	0.371c	0.391b	

Planned mean comparison for stages of N application with statistical significance			
Contrast	1st mean	2nd mean	Sign.
Full vs. Split	0.395	0.389	NS
Full early vs. Full mid	0.410	0.379	**
3 Split vs 2 Split	0.437	0.373	**
Early+mid vs.(Early+late)+(Mid+late)	0.351	0.384	**
Early+late vs. Mid+late	0.362	0.405	**
Year 1 vs. Year 2	0.398	0.384	**

$LSD_{(0.05)}$ for Tillage = 0.01, Nitrogen = 0.01, Stage = 0.01 Interactions T x N = **, T x S = **, N x S = **, T x N x S = ** Means followed by different letters of the various categories are significantly different at 5% level of probability using LSD test. NS = Not significant

** = Significant at 1% level of probability

The interaction of all the three factors i.e. tillage practice, nitrogen level and fertilizer application stages significantly affected post harvest soil N. Significantly highest amount of 0.536 g kg^{-1} post harvest soil N content was resulted under NT at 180 kg N ha^{-1} when applied as three splits. While 0.525 g kg^{-1} post harvest soil N content were recorded by NT at 180 kg N ha^{-1} under two splits i.e. at 5 leaves and pre tasselling. Lowest amount of 0.321 g kg^{-1} post harvest soil N was left over under CT at 120 kg N ha^{-1} applied as two splits i.e. at 5 leaves and pre tasselling. Higher residual nutrient status under NT has also been reported by Moschler *et al.* (1972) who applied equal amounts of fertilizer to CT and NT plots and found higher yields for NT, coupled with some increase in residual nutrients, strongly suggested that a more efficient utilization of fertilizers occurred under NT system. Similary, Wienhold and Halvorson (1998) showed that NT had a higher level of total soil N than CT. The results are not in line with Rasse and Smucker (1999), they found that the nitrate concentration were greater under CT system though total nitrate-nitrogen leached in this study was similar or slightly lower for no-till. Dury *et al.* (1993) also found greater nitrate-N concentrations for the CT treatment. Similarly, Halvorson *et al.* (2006) reported that the NT system generally had a lower level of residual soil NO_3-N than CT at all N rates.

High soil inorganic N with application of higher levels of N has also been reported by Rozas *et al.* (2004) who reported that mineral N was significantly greater for the highest N rates applied at the six leaf stage at the end of the growing season and indicated that high N rates applied at this stage exceeded crop requirements. Similar results have been reported by Jokela and Randall (1997). Likewise, Jokela and Randall (1989) suggested that higher amount of residual nitrate-N at the end of the season from N applied at the 8 leaf stage has a greater carryover potential for the next years production. Gehl *et al.* (2005) reported that the 300 kg N ha^{-1} treatment had a higher soil NO3-N content as higher compared with 68 and 109 kg N ha^{-1}.

Tissue Nitrogen Content

Data collected during 2004 and 2005 were combined and presented in Table 4. Tillage practices and N application at various growth stages had significant impact on tissue N contents. Significantly more N (8.96 g kg^{-1}) was accumulated by plants under CT system as compared with (8.33 g N kg^{-1}) under NT.

Significant differences for tissue N content were observed among various fertilizer application stages. Significantly higher tissue N content (9.50 g kg^{-1}) was recorded when nitrogen was applied as full dose at 5 leaves stage as compared with when applied at sowing (7.90 g kg^{-1}). These results reflected that fertilizer N was efficiently utilized when available at later stage of plant growth. These findings are in confirmation with Jung *et al*. (1972) and Rozas *et al*. (2004). The interaction of the three factors i.e. tillage practice, N levels and its application at various growth stages had significant effect on tissue N content.

Halvorson *et al*. (2006) noted that the amount of N in the corn residue at harvest increased with increasing N rate in both CT and NT systems. Jung *et al*. (1972) reported that percent N in the grain and tissue increased significantly with an increasing rate of applied N. Furthermore, they also reported that N concentration in grain and tissue generally increased as the time of N application was delayed but Al-Kaisi and Yin (2003) reported that N uptake by plant and grain at the six leaf growth stage was statistically identical for the N rates of 140, 250 and 360 kg ha^{-1}. Rozas *et al.* (2004) reported that the N recovery by the maize crop was greater when N was applied at six leaf stages than when N was applied at planting time. Additionally, it appeared that the recovered N was predominantly deposited into the grain as previously reported by Bigeriego *et al.* (1979). They argued that the larger rate of N recovery with the six leaf stage which was just before maximum plant need might be due to lower N losses through denitrification or leaching or lower N immobilization in organic forms (Wells and Bitzer., 1984).

CONCLUSION

Conventional tillage proved superior in term of yield and tissue N content except post harvest soil-N as compared to No-tillage. Yield significantly improved up to 120 kg N ha^{-1} however, additional N up to 180 kg ha^{-1} failed to induce any increase. Split application significantly increased yield as compared to sole application. Within split application, three splits resulted higher residual soil-N. Plant tissue N content was higher and soil residual N was lower with sole application of N at 5 leaves stage as compared to sole single dose at sowing.

Table 4. Tissue N content of maize as affected by levels of N and its application at various plant growth stages under no tillage (NT) and conventional tillage (CT) systems over the two years.

Tillage	Stages	N (kg ha^{-1})			Mean
		60	120	180	
			T x N x S		T x S
			g kg^{-1}		
NT	S1	7.61	8.29	6.78	7.56
	S2	9.67	8.31	8.18	8.72
	S3	7.92	8.49	9.19	8.53
	S4	9.49	7.53	7.59	8.20
	S5	7.39	8.75	8.40	8.18
	S6	8.79	8.98	8.58	8.78
CT	S1	8.18	8.27	8.29	8.25
	S2	10.00	9.47	11.38	10.28
	S3	9.58	9.47	8.91	9.32
	S4	8.09	8.75	9.84	8.90
	S5	8.31	8.27	8.42	8.33
	S6	9.03	8.36	8.73	8.71
			T x N		T
NT		8.48	8.39	8.12	8.33 b
CT		8.87	8.76	9.26	8.96 a
			N x S		S
	S1	7.90	8.28	7.54	7.90 d
	S2	9.83	8.89	9.78	9.50 a
	S3	8.75	8.98	9.05	8.93 ab
	S4	8.79	8.14	8.72	8.55 bc
	S5	7.85	8.51	8.41	8.26 cd
	S6	8.91	8.67	8.65	8.74 bc
	Mean	8.67	8.58	8.69	

Planned mean comparison for stages of N application with statistical significance			
Contrast	1st mean	2nd mean	Sign.
Full vs. Split	8.70	8.62	NS
Full early vs. Full mid	7.90	9.50	**
3 Split vs 2 Split	8.93	8.52	NS
Early+mid vs.(Early+late)+(Mid+late)	8.55	8.50	NS
Early+late vs. Mid+late	8.26	8.74	NS
Year 1 vs. Year 2	8.69	8.61	NS

$LSD_{(0.05)}$ for Tillage = 0.29, Nitrogen = NS, Stage = 0.63 Interactions T x N = NS, T x S = NS, N x S = NS, T x N x S = *

Means followed by different letters of the various categories are significantly different at 5% level of probability using LSD test.

NS = Not significant * = Significant at 5% level of probability, ** = Significant at 1% level of probability

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