Bulgarian Journal of Agricultural Science, 15 (No 6) 2009, 533-543
Agricultural Academy

TILLAGE AND COVER CROP EFFECTS ON MAIZE YIELD AND SOIL NITROGEN

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Abstract

OZPINAR, S., 2009. Tillage and cover crop effects on maize yield and soil nitrogen. *Bulg. J. Agric. Sci.,* 15: 533-543

Tillage and spring kill cover crop may affect crop N-accumulation and subsequent N release to the soil, thereby influencing maize (*Zea mays* L.) uptake and yield. We examined the influence of three tillage practices [conventional tillage with mouldboard plough (MP) as using traditionally tillage, chisel tillage (CT), shallower rototiller tillage (ST)], one cover crop management systems [common vetch (*Vicia sativa* L.)] on cover crop N accumulation, soil N, and maize biomass yield and N uptake. An experiment was conducted on a clay-loam soil from 2005 to 2008 in a semi-arid region in Mediterranean conditions. Cover crop N accumulation was higher with MT than ST and CT due to increased biomass yield over all year average. However, maize biomass yield and N uptake were found higher in ST than in MT and CT. Soil N at 0-30 cm depth at maize planting was higher in ST followed by CT and MT. Similarly, soil N was determined higher in ST at the end of establishment year followed by MT and CT, respectively. The results can be applied in regions where cover crops can be grown in the winter to reduce soil erosion and N leaching and where tillage intensity and N fertilization rates can be minimized to reduce the costs of energy requirement for tillage and N fertilization while optimizing crop production.

Key words: crop management systems, N-accumulation, maize N-uptake, maize

Introduction

In the west part of Turkey, it has been intensively cropped for long-term in rainfed cropping predominates, with annual average rainfall ranging from about 400 to 700 mm concentrated in the autumn and winter months, and generally suffers serious sustainability problems arising from decline in the chemical and physical fertility of the soil. Thus the cropping is largely confined to a single crop per year, with wheat, barley and sunflower in the drier parts, and maize and tomatoes in the wetter ones, usually in summer. The traditional system of maize intercropped with wheat or continuous wheat is still evident. Although modest fertiliser inputs appear to be used, cereal grain yields are low (4 Mg ha^{-1}) (Ozpinar, 2006), crops are often weedy and nitrogen deficient, soil structure is poor. Such as crops intercropped with legumes can improve soil nitrogen status (Chalk, 1998) when reducing tillage with crop residue retention conserved soil mois-

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ture and increased crop yields (Lal, 1989). Therefore a more controlled experiment was set up to test, in particular, whether breaking the sequence of continuous wheat with another cereal such as maize or legume crop (green manure) was beneficial.

A legume cover crop, such as common vetch, can supply most of N required for maximum maize yield (Clark et al., 1997a; Bayer et al., 2000). Common vetch residue can decompose rapidly in the soil due to its high N concentration and low C/N ratio (Sainju and Sing, 1997; Kuo et al., 1997; Vaughn and Evanylo, 1998) and allow for synchrony of N release from the residue with maize N demand (Power et al., 1991; McVay et al., 1989). Vetch increased maize yield similar to fertilizer N rates of 66 to 200 kg ha^{-1} (Sainju and Sing, 1997). In addition, vetch can improve soil water quality compared with bare fallow by reducing erosion during fall, winter, spring, and increasing organic matter (Sainju and Sing, 1997). Nitrogen supplied by vetch can be influenced by tillage (Wilson and Hargrove, 1986; Sarrantonio and Scott, 1988; Dou et al., 1994) and also time of kill (Wagger, 1989). Clark et al. (1997a, 1997b) reported that delaying the spring kill date of vetch from 2 to 6 weeks increased its biomass yield and N accumulation. As a result, delayed planting of maize following late kill also increased its yield and N uptake in the conservation tillage system because more N was supplied and soil moisture conserved by the residue. Nitrogen released by vetch residue can be mineralized and plants absorb N. Because tillage can influence the degree of residue incorporated into the soil and subsequent N mineralization, the type of tillage may affect the synchrony of N release from the residue with maize N demand (Power et al., 1991). In mouldboard plough system, increased incorporation killed vetch residue into soil followed by planting may not increase maize N uptake and yield. In contrast, shallow and no-tillage systems with residue retention on or near the surface of soil can improve nutrient cycling over the long-term (Lal, 1989; Blevins and Frye, 1993), but such as systems combined with the legumes rotations encourage heavy weed population.

It hypothesize that in study tillage affects N release from cover crop with common vetch, consequent soil N, and subsequent N uptake and maize biomass and grain yield. Our objectives were to determine the effects of tillage on cover crop N accumulation, soil N, and subsequent maize biomass and grain yield and N uptake.

Materials and Methods

Study site and soil

The experiment was conducted from 2005 to 2008 at the Dardanos Experimental Area, in Canakkale province (elevation: 10 m; latitude: 39^o 30’N; longitude: 26^o 80’E), the southwest of the Marmara Region, western Turkey. The climate of the region is semi-arid with cold rainy winters and hot dry summers (typical Mediterranean climate). Irrigation was required to obtain appropriate grain yields during summer period, since precipitation was low (146 mm) during the maize growing period and temperatures were high (mean temperature 20.5^{0}C) (Figure 1) with 76.5% relative humidity over the long-term (33 years) average. The soil (Typic Haploxererts by US soil taxonomy and Eutric Vertisols by FAO/UNESCO) at the study site had a clay loam texture in the 0-79 cm depth. The main soil characteristics are presented in Table 1. The experimental area prior to the start of this experiment was being put to general cultivation of winter wheat *(Triticum aestivum* L.*)* and vetch (*Vicia sativa* L.) in an annual sequence under semi-arid conditions since 2000 year. The experiment was commenced in October 2005 with vetch in the winter followed by maize in the spring. This sequence of cropping continued for 4 seasons and ended in September 2008 after the harvest of maize. Every year, the experiment was conducted in the same plots. This paper however, reports the results on N accumulation of maize crop and on soil fertility as influenced by vetch green manure.

Tillage experiment

Three tillage systems were used. These were conventional tillage with mouldboard plough (MT) (22-25 cm depth) which is used to traditionally by farmers

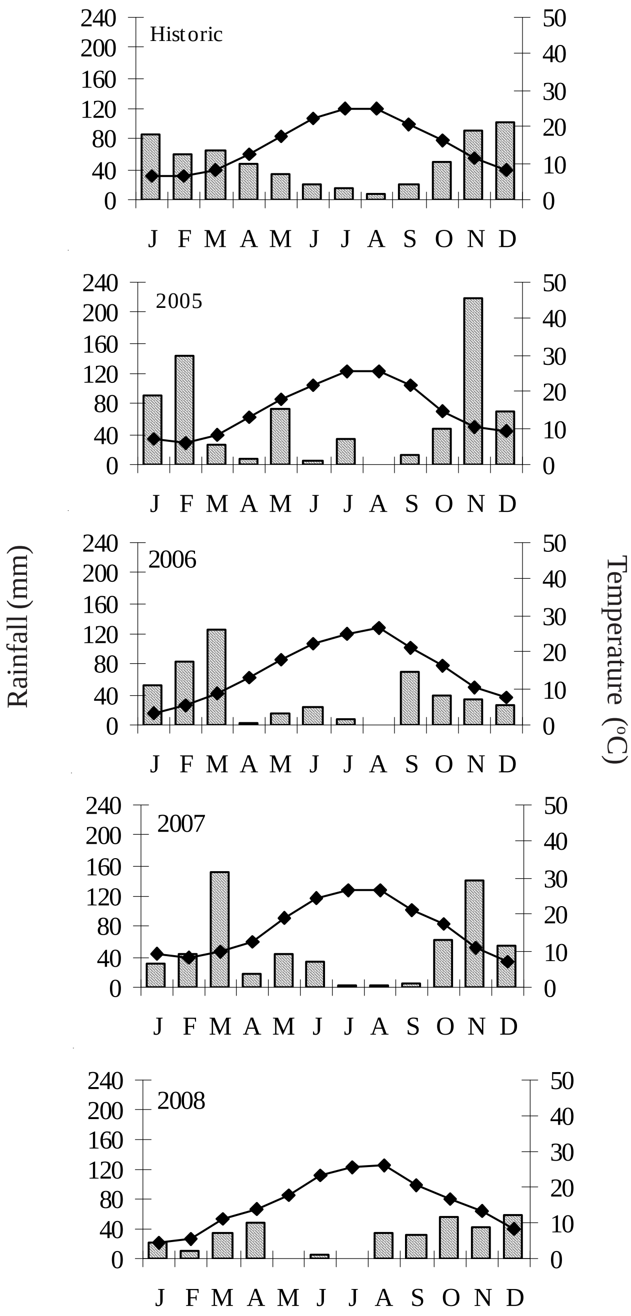

Fig. 1. Monthly precipitation and mean temperature for the historic period (1975–2008) and for the experimental period (2005–2008). The number at the top indicates time of irrigation application for maize over average year

in region, shallower rototiller tillage (ST) (10 cm depth) and reduced tillage with chisel tillage (CT) in depth of 35 cm. The description and dates of cultural practices used for cover crop-maize cultivation practices dates are shown in Table 2. The MP, ST and CT plots were tilled in October for cover crop planting and in April through May of the following year for cover crop incorporation and maize planting. After cover crop moving and thorough drying of the residue in the field, plots were harrowed two to three times using a disc harrow until residues were broken into small pieces before ploughing, rototilling and chiselling. Because residues were broken into small pieces by moving and harrowing, most were uniformly spread throughout the plot even after MT, CT and ST. Tillage treatment plots were 40 m long and 6 m wide with three replications.

Green manure and crop management

The experiment consisted of a green manure-maize rotation from December 2005 until the end of the growing season in 2008. The green manure with vetch and maize establishment sequence was as follows: green manure in December 2004 and maize in May 2005; in December 2005 and maize in May 2006; green manure in December 2006 and maize in May 2007; green manure in December 2007 and maize in May 2008. Vetch seed was drilled at 120 kg ha^{-1} using a row spacing of 15 cm. No fertilizer, herbicide, or insecticide was applied. At 20% flowering time, vetch was harvested from three 1-m^2 areas within each plot and weighed in the field for biomass mass yield determination. A subsample (≅100 g) was collected for determination of dry matter yield and N concentration, the rest was returned to the harvested area where it was spread uniformly by hand. Plants were oven-dried at 60°C, weighed, and ground to pass a 1-mm screen. Residues were allowed to decompose in the soil for 9 to 15 day, except 2005 including 5 days, before fertilization and maize planting except 2005 growing season which was performed 5 days in post- cover crop killing.

Maize sowing

Maize was sown generally at beginning May, and

Table 1
Main soil properties at the beginning of the experiment

Depth, cm	Horizon	Sand, g kg^{-1}	Silt, g kg^{-1}	Clay, g kg^{-1}	Texture[a]	EC, dS m^{-1}	OC, g kg^{-1}	PH	P, mg kg^{-1}	$CaCO_3$, %
0-27	Ap	399	298	304	clay loam	177	13.4	7.7	46.68	13.5
27-49	A1	386	270	339	clay loam	255	11	8	43.05	14.1
49-79	A2	390	247	363	clay loam	122	4.8	8	49.81	9.9

[a] USDA texture classification, EC: Electrical conductivity; OC: Organic carbon.

Table 2
Dates of cultural practices used for cover crop kill and maize

Practices	2005	2006	2007	2008
Cover crop planting	28 Dec.2004	07 Dec.2005	08 Dec. 2006	24 Dec.2007
Cover crop kill	5-May-05	2-May-06	24 Apr. 2007	24 Apr. 2008
Maize planting	12-May-05	11-May-06	9-May-07	7-May-08
Maize harvest	20 Sep. 2005	13 Sept.2006	12 Sept.2007	08 Sept.2008
Soil sampling				
Before cover crop kill	24 April 2005	2-May-06	13 Apr. 2007	17 Apr.2008
Maize planting	10-May-05	11-May-06	9-May-07	7-May-08
Maize harvest	06 Oct.2005	27 Oct.2006	13 Sep.2007	15 Sept.2008

managed under MT, ST and CT in 2005, 2006, 2007 and 2008. Maize, variety “Agromar MF 714”, was sown within the first 7 cm, depth 19 cm apart within the row and 76 cm between rows in a plant population of 68 000 plants ha^{-1}. These clay-loam soils are able to keep enough residual moisture to allow germination of seeds. Maize plants were thinned approximately 6 weeks after sowing by hand hoeing. Weeding was done by hand hoeing. Canal water was used for irrigation when needed. Starter fertilizer was applied in a band at planting in all maize plots at a rate of 50, 50, and 0 kg ha^{-1} in the form of a compound of N, P and K, respectively.

No application of fertilizer was done after planting. In this region, the maize crop needs between 150 to 200 kg N ha^{-1} of fertilizer during the growing period. Previous studies in this region indicated that a preceding vetch crop could provide between 110 to 200 kg N ha^{-1} to the subsequent crop regarding to tillage management systems (Ozpinar and Baytekin, 2006), therefore, maize probably had adequate N in the vetch-maize rotation, regardless of the management system.

Data collection for maize yield and soil quality indicators

In August of each year, two middle rows (40.0 by 1.52 m) of maize were hand-harvested from each plot for biomass yield determination. Five representative plants were weighed and chopped, and a known amount of subsample was collected in the field. The subsample was oven-dried at 60°C to a constant, weighed again for dry matter yield determination, and ground to pass a 1-mm screen for N analysis. Soil planting samples were collected (30 cm depth) from all plots at 7 to 11 days before cover crop kill and at maize harvest (Table 2). The sampling was performed annually and collected from a push tube from 10 places within the plot after removing visible plant residues and then composited, air-dried and ground to pass a 2-mm sieve for N analysis. Nitrogen concentration in the cover crop and maize samples was determined by the CHN analyzer (EuroVector, Euro-EA3000, Italy) using 1-1.5 mg of crop samples and 10 mg of soil samples. Nitrogen accumulation in cover crop and maize was determined by multiplying dry matter weight by N concentration, except 2008. In 2008, total N yields for cover crops and maize could not be calculated due to cover crop and maize samples mistakenly being discarded before determining N concentration.

Analysis of variance was performed for all response variables for a split-plot treatment arrangement using the procedures of the MSTAT-C. The ANOVA procedure was used to evaluate the significance of each treatment for all measurement parameters. Treatment means were separated by the least significance difference (LSD) test. All significant differences are reported at the 5% level.

Results

Cover crop biomass yield and nitrogen accumulation

The biomass yield was significantly affected by tillage systems ($P<0.05$) for all experimental years, except in 2005 (Table 3). Although there is no significant difference among tillage treatments, the dry biomass yields in 2005 were higher in MT and CT when compared with ST. Similarly, in 2006 and 2007, a higher level of biomass was found in MT, but ST was produced the lowest biomass in 2006 while it was as productive as CT in 2007. In contrast, in 2008, the highest level of biomass was produced under ST which had had the lowest values in the first 2 years. On the other hand, a significant tillage-by-year interaction was found in biomass yields. All tillage treatments produced their maximum biomass in 2005, while ST, CT and MT produced its minimum values in 2006, 2007 and 2008, respectively. When all the experimental years are considered, the maximum biomass yield was determined for 2005, followed by 2008, 2007 and 2006, respectively, when the lowest yield was obtained from treatments over 3-treatment average.

Maize biomass yield and nitrogen uptake

Maize biomass yield, N-concentration, and N-uptake varied between experimental years and fluctuated according to growing seasons (Table 4). In 2006, maize biomass yield was higher with ST than with MT and CT, although there is no significant difference between tillage treatments in 2005. Similarly, in 2008, a higher level of biomass was found in ST followed by CT and MT. In contrast, in 2007, the highest level of biomass was produced under MT, but ST was as productive as CT and less productive than MT. Moreover, a significant tillage-by-year interaction was found in biomass yield that all treatments produced their maximum biomass yield in 2008. N-concentration and N-uptake varied significantly between tillage treatments. N-concentration was found higher for ST compared with MT in 2005, while CT produced the lowest, although there was unaffected by tillage treatments in 2006 and 2007. Similarly, N-uptake was higher with ST in 2005 and 2006 than MT when MT produced higher in 2007, although N-uptake was not affected by tillage. In considering year, N-uptake by maize was observed the highest in ST treatment in 2006 with 302 kg ha^{-1} followed by MT with 277 and 272 kg ha^{-1} in 2007 and 2006, respectively. N-uptake after across 3 year average was lower in CT with 142 kg ha^{-1}, while it was the highest in ST with 232 kg ha^{-1}. Averaged across treatments, N-uptake 60% higher in 2006 and 4% lower than in 2005 and 2007, respectively, but N-concentration was 60 and 16% higher in 2006 than in 2005 and 2007.

Considering total N-content in soil at the beginning period and the end of the establishment year, significant differences were found in all tillage treatments for each year (Table 5). Higher soil N-content was found in ST compared with MT. On the other hand, increased soil N after ST was also associated with a significant increase in grain yield, as compared to other treatments over 3-year average (Figure 2). In 2005, however, the increased availability of soil N at maize planting with CT compared to MT did not improve maize biomass yield and N uptake because yield was

Table 3

Effect of tillage on cover crop biomass yield, N-concentration, and N-accumulation in 2005, 2006, 2007 and 2008

Tillage[a]	Biomass yield, mg ha^{-1}						N-concentration[c], g kg^{-1}						N-accumulation, kg ha^{-1}					
	2005	2006	2007	2008	LSD[b]	Mean	2005	2006	2007	2008†	LSD	Mean	2005	2006	2007	2008†	LSD	Mean
ST	6.05aA	0.79bC	3.84bB	4.86aB	2.66	3.88	13.2aC	32.5aB	41.9aA		2.09	29.2	77aB	26bC	161bA		49.41	89
MT	6.57aA	4.18aB	5.01aB	4.05bB	1.06	4.95	10.4bC	30.7aB	44.8aA		1.5	28.6	68aC	128aB	224aA		17.6	140
CT	6.17aA	3.79aBC	3.18bC	4.38abB	1.17	4.38	10.6bC	32.2aB	43.5aA		3.97	28.8	66aB	122aA	138bA		37.79	109
LSD	NS	0.6	0.79	1.94			1.8	NS	NS				NS	25.82	29.13			
Mean	6.26	2.92	4.01	4.43	-	4.4	11.4	31.8	43.4		-	28.8	70	92	174		-	112

Means in the same row and columns followed by the same capital and lower case letters, respectively, are not significantly different at $P < 0.05$.

[a] Tillage are ST, shallow; CT, conventional; DD, double disc.

[b] LSD between the plots within a row or a column ($P < 0.05$).

[c]:N concentration for 2008 were not analyzed.

† Cover crop N concentrations and accumulation are not available for 2008.

not influenced by tillage. Similarly, in 2007, ST was increased soil N content at the same period, but did not observed any affect on biomass yield. In contrast, in 2006, ST produced soil N as much as MT at the planting time, but ST produced higher amount of biomass yield than MT (Table 4). Comparing year over treatments, soil N was increased after each treatment performed from year to year when vetch cover crop was enhanced soil N during the experimental period in progressing. By the end of the establishment each year, in general, it was occurred a decreasing or equal in soil N compared at the planting time for each treatments, except 2005.

Grain yield was influenced by tillage treatments when ST was produced the highest grain yield (Figure 2) compared to MT (Table 4). In considering experimental years, the highest grain yield according to each treatment was determined in the last experiment year.

Discussions

Although tillage interacted with cover crop to influence cover crop biomass yield and N-accumulation, the higher biomass yield and N-accumulation with ST over 3-year average (Table 3), but ST produced its minimum values in 2006 due to volunteer weed regrowth mostly such as scentless mayweed (*Matricaria perforata*), wild mustard (*Sinapsis arvensis*), etc., under no chemical application at early plant growth stage. In addition, ST combined with the legume rotations such as vetch encourages heavy weed population compared with MT, but weed emergency fluctuated according to growing season depends on planting time and soil temperature in seedbed during emergency period when its population increased in warmer period (unpublished data). Similarly, Fisher et al. (2002a) observed that conservation tillage such as no-till increased weed population in legume-cereal rotations, and this population appeared to be increasing over the years of the experiment. MT produced its minimum biomass in the last year of experiment, while CT produced its lowest value in 2007. The one of important causing from the lowest biomass for CT

Table 4

Effect of tillage, cover crop on maize biomass yield, N concentration, and N accumulation in 2005, 2006, 2007 and 2008

Tillage[a]	Biomass yield, mg ha^{-1}						N-concentration[c] g kg^{-1}						N-uptake, kg ha^{-1}					
	2005	2006	2007	2008	LSD[b]	Mean	2005	2006	2007	2008†	LSD	Mean	2005	2006	2007	2008†	LSD	Mean
ST	7.61BC	10.02aB	9.52aB	19.68aA	8.85	11.71	17.5aB	30.5aA	28.5aA		8.83	25.5	135aB	302aA	259aA		89.6	232
MT	7.80C	8.07bBC	10.53aAB	10.91bA	2.55	9.33	15.0aB	33.5aaA	26.8aB		8	25.1	118aB	272aA	277aA		100	222
CT	6.15BC	5.21cC	9.84aAB	12.59bA	4.28	8.45	5.7bC	30.5aA	23.6aB		8.74	20	34bB	162bA	232aA		123	142
LSD	NS	1.71	NS	5.53			4.57	NS	NS				73.66	46.29	NS			
Mean	7.2	7.8	10	14.4	-	9.83	12.7	31.5	26.3		-	23.5	95	245	256		-	199

Means in the same row and columns followed by the same capital and lower case letters, respectively, are not significantly different at P < 0.05.

[a] Tillage are ST, shallow; CT, conventional; DD, double disc.

[b] LSD between the plots within a row or a column (P < 0.05).

[c] :N concentration for 2008 were not analyzed.

† Cover crop N concentrations and accumulation are not available for 2008.

in all experimental year, except 2006, was as previous wheat residues. It could not exactly be chopped at the time of tillage (December) because of wetter soil conditions and residues, causing a rough seedbed. This seedbed slightly delayed the emergence time (unpublished data) compared to other tillage treatments that it was decreased the biomass yield in advance period of plant growth stage. When all the experimental years are considered, the maximum biomass yield was determined for 2005, followed by 2008, 2007 and 2006, respectively (Table 3). Total rain values from February to the end of April were registered the higher in 2005 and followed by 2007 when mean temperature was registered lower in the first 2 years than in the later 2 years, 9.1 and 10.2° C, respectively (Figure 1). The period from February to April is important for plant establishment which has an influence on the amount of biomass produced (Cadavid et al., 1998). Growth of cover crop such as common vetch is more influenced by temperature increasing, thereby resulting in increased biomass production and N-accumulation (Clark et al., 1995; Sainju et al., 1998). Average monthly temperature increased from 9.1° C in December 2005 to 17.7° C in May 2006, from 7.5° C in December 2006 to 18.8° C in May 2007 and from 6.8° C in December 2007 to 17.7° C in May 2008. Clark et al. (1995) observed that from early April to Mid-May, vetch biomass amount increased 2 times and N-accumulation increased 1.5 times.

The effects of tillage and cover crop on soil N were minimal in CT compared with ST and MT (Table 5) probably N mineralized from cover crop residue converted into N have reduced in CT, as is commonly observed during all experimental years. Moreover, CT produced lower N-uptake by maize compared to MT over 3-year average (Table 4). Similarly, Fischer et al. (2002) observed that N-uptake by maize under no fertilizer conditions across 3 year average was increased in tilled by mouldboard plough than in conservation tillage due to lower mineralization around planting in untilled practices. Averaged across treatments, higher biomass yield and N-uptake in 2007 than in 2006, except 2005 (Table 4) may have resulted from increased soil moisture and N mineralization due to in-

Table 5
Effect of tillage and cover crop on soil total N at maize planting and harvest in 2005, 2006 and 2007

Tillage[a]	At planting						At harvesting					
	2005	2006	2007	2008†	LSD[b]	Mean	2005	2006	2007	2008†	LSD	Mean
	mg kg^{-1}											
ST	112.3bC	133.3aB	175.0aA		12.85	140.2	135.7aA	135.7aA	88.7bB		23.7	120
MT	56.3cB	133.3aA	136.0aA		16.5	108.6	126.7bA	115.7bA	101.0aB		29.52	114.4
CT	126.7aA	96.7bC	119.0aB		19.71	113.8	120.7bA	119.3bA	98.3bB		24.09	112.8
LSD	13.81	0.36	NS				68.61	43.85	28.1			
Mean	98	121.1	143.3		-	120.9	127.7	123.6	96		-	115.7

Means in the same row and columns followed by the same capital and lower case letters, respectively, are not significantly different at $P < 0.05$.

[a] Tillage are ST, shallow; CT, conventional; DD, double disc.

[b] LSD between the plots within a row or a column ($P < 0.05$).

† Cover crop on soil is not available for 2008.

creased rainfall and the amount of N supplied by cover crop residue. June and July rainfall is critical for maize growth and total rainfall from April to August were higher in 2005 with 118 mm than in 2007 and 2006 with 100 and 52 mm, respectively. Although soil moisture stress to maize was prevented by using irrigation equivalent to 25 mm of rain once or twice a month during dry periods (Figure 1), moisture stress may not have been completely prevented during May to August in 2006. In contrast, higher rainfall from April to August probably decreased moisture stress and increased soil N mineralization and availability (Table 5), thereby increasing maize yield and N-uptake in 2007 compared to 2006. Soil moisture content can influence N mineralization and availability and subsequent maize growth and N-uptake (Clark et al., 1995; 1997b). Lower biomass yield, however, was determined in 2005, although the highest rainfall with 118 mm observed during this growing period. It could be attributed to an allopath problem occurring at early plant growth stage that causes lower plant population comparing with other growing seasons because maize planting was performed after 5 days cover crop killing to catch the maize planting time. Furthermore, lower biomass yield in the first year of the field experiment could be also attributed to an insufficient N supplied by green manure left on the soil surface for reaching maximum maize growth (Dou et al., 1994).

Soil N was affected by tillage treatments (Table 5) and higher soil N-content in ST may have resulted from the placement of plant residue due to less tillage and soil redistribution as compared to MT in both planting and harvesting period over the 3-year average (Ghuman and Sur, 2001). In contrast, MT with incorporation of the residue to a greater depth and intensive soil disturbance promotes rapid decrease of soil N (Blevins et al., 1983), and negatively affects crop productivity. Bayer et al. (2000) also pointed out that conservation tillage produced higher N content than MT, which was probably the cause of result the lowest soil organic matter losses (due to erosion and oxidation) and the highest addition of crop residues. In contrast, other researchers observed that conventional tillage with mouldboard plough provided higher soil N relative to

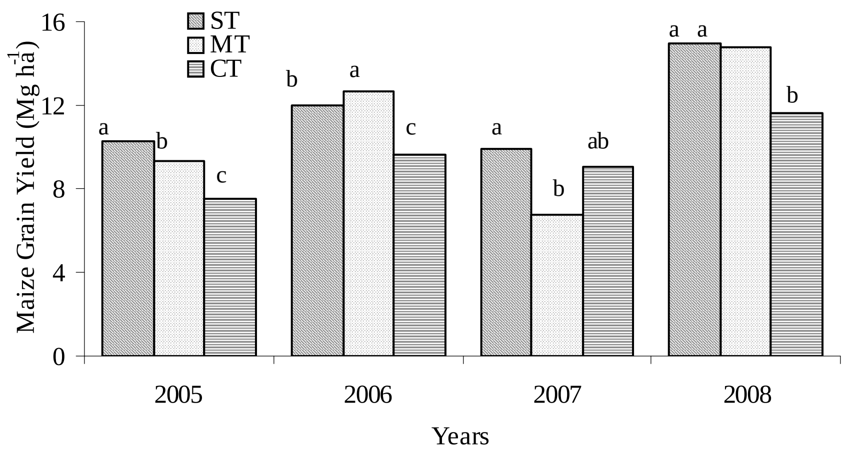

Fig. 2. Grain yield (Mg ha^{-1}) of maize under ST, MT and CT in 2006, 2007 and 2008. Bars with the same letter at the top are not significantly different by the least square means (P ≤ 0.05)

conservation tillage (Dou et al., 1994; Wilson and Hargrove, 1986; Sarrantonio and Scott, 1988; Sainju and Sing, 1997). Sainju et al. (2002) pointed out that there were significant differences among tillage systems; that chisel tillage provided more soil N than mouldboard plough. On the other hand, increased N after ST was also associated with a significant increase in grain yield, as compared to other treatments over 3-year average (Figure 2). In considering tillage treatments, soil N did not always affect maize biomass yield and amount of maize N-uptake. However, when comparing year over treatments, soil N was increased after each treatment performed from year to yea. Similar results was observed by Wani et al. (1995), legumes can increase the content of soil N in the long run in comparison with the short run. By the end of the establishment each year, in general, it was occurred a decreasing or equal in soil N compared at the planting time for each treatments, except 2005, could be attributed to the lowest yield of biomass observed in this growing season (Table 4). Moreover, it was observed more decreasing of soil N in 2007 that it may be result from higher biomass yield compared with 2005 and 2007 in considering each treatment.

In comparing to MT, ST was produced the highest grain yield (Figure 2) may be due to higher soil N (Table 5), and then increased N-uptake (Table 4). In contrast, Sarrantonio and Scott (1988) founded that maize grain yield in the short run was higher with MT than with conservation tillage; in contrast, others (Fischer et al., 2002b) observed that yield in the long run yielded more in conservation tillage than mouldboard plough tillage. The highest grain yield according to each treatment was determined in the last experiment year may be due to cover crop N supply as green manure. Dou et al. (1994) determined that N supplied by green manures left on the soil surface during the first year of a field experiment was insufficient for reaching maximum maize growth. Fischer et al. (2002) observed such as results that maize grain yield was increased in vetch-maize rotation regarding to year progressing, especially in conservation tillage system when conventional tillage fluctuated according to year.

Conclusions

Over all year average, cover crop killing in the spring significantly increased N-accumulation in MT followed by CT when ST produced the lowest due to high weed population. Incorporation of such residue into the soil surface in ST increased soil N compared with MT by increasing N mineralization from the residue. ST also increased maize biomass yield and N-uptake. Increased soil moisture conservation by residue especially at early crop growth stage, followed by increasing N mineralization rate, may have increased maize yield and N-uptake in ST compared with MT and CT. Maize grain yield also higher in ST than MT and CT. Conservation tillage such as ST and cover crop management practices can be applied to control soil erosion and reduce N leaching in the regions where cover crops can be grown in the winter and costs for energy requirement for tillage and N fertilization are a major concern. Furthermore, it is important to emphasize that more than 4 years would be required to show the real long-term benefits of conservation tillage and cover crop management in this environments. Thus, all of the treatments described here will be continue in the same plots for a long-term to see benefits of management effects on maize production in this environment.

Acknowledgements

We are grateful to the Canakkale Onsekiz Mart University Scientific Research Projects Commission for having funded this project (Project No 2009/29). Appreciation is expressed to the COBILTUM laboratory staffs and other individuals who provided assistance in analysing soil and plant tissue samples.

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Received May, 15, 2009; accepted for printing September, 12, 2009.