THE INFLUENCE OF DIFFERENT TILLAGE PRACTICES ON THE SOIL MOISTURE AND NITROGEN STATUS

UTICAJ RAZLIČITIH NAČINA OBRADE NA SADRŽAJ VLAGE I AZOTA U ZEMLJIŠTU

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Abstract

The tillage systems differently affect the soil fertility and the maize yield. Irrigation is prominent cropping practice for yield increasing irrespective to fact that rain-fed is still the most broadly applied cultivation practice in the world. The aim of this study was to investigate effects of different tillage systems (conventional, reduced and no-till) and fertiliser levels on changes of the soil N content during three vegetative stages (sprouting, anthesis and harvesting), as well as maize grain yield under rain-fed and irrigation conditions in 2005-2008. The rain-fed cropping only in no-till cropping induced increase of soil moisture during anthesis. The highest N amount in soil in dry season (2008) was kept under conventional tillage in rain-fed cropping. As well, the highest grain yield was observed with conventional tillage practice. Irrigation diminished differences between cropping years and fertilization regimes.

Keywords: maize, tillage, nitrogen, soil moisture, yield

Sažetak

Sistemi obrade razliĉito utiĉu na plodnost zemljišta i prinos kukuruza. Navodnjavanje je najpoznatiji naĉin koji utiĉe na povećanje prinosa, bez obzira na ĉinjenicu da je gajenje kukuruza u uslovima prirodnog vodnog reţima još uvek najraširenija praksa u svetu. Cilj ove studije je bio da se istraţe uticaji razliĉitih sistema obrade (konvencionalne, redukovane i bez obrade) i nivoa Ċubrenja na promene u sadrţaju zemljišnog azota tokom tri vegetativne faze (nicanje, cvetanje i berba), kao i prinosa zrna kukuruza gajenog u uslovima prirodnog vodnog reţima i navodnjavanja tokom 2005-2008.

Gajenje u uslovima prirodnog vodnog reţima je samo u sistemu bez obrade povećalo vlagu zemljišta u fazi cvetanja. Najviši nivo azota je zadrţan u zemljištu u uslovima prirodnog vodnog reţima tokom sušne sezone (2008) kod konvencionalne obrade. TakoĊe, najviši prinos je ostvaren pri konvencionalnoj obradi. Navodnjavanje je umanjilo razlike izmeĊu godina i reţima Ċubrenja.

Ključne reči: kukuruz, obrada, azot, zemljišna vlaga, prinos

DETAILED ABSTRACT

The different tillage systems could affect the soil fertility and the maize yield in diverse way. From that point of view, the irrigation represents the widespread system which has as a consequence yield increase, irrespective to fact that rain-fed cropping is still the most abundant cropping system in the world. The aim of this study was to investigate effects of different tillage systems (conventional, reduced and no-till) and different fertiliser levels (without fertilisation - F1; 150 kg N, 105 kg P_2O_5, 75 kg K_2O_5, ha^{-1} - F2; 300 kg N, 211 kg P_2O_5, 150 kg K_2O ha^{-1} - F3) on changes of the soil N content and maize grain yield under rain-fed and irrigation conditions, during three vegetative stages in 2005-2008. The hybrid ZP SC 704 was hand sown in four-replicate trial by the block system, at the sowing density of 60,600 plants ha$^{–1}$. Meteorological data (Table 1) show that 2008 was the driest year, while highest precipitation level was observed during season of 2007. Soil samples were taken from the effective rizosphere zone, during the three most important vegetative stages: about 30 days after sowing, at anthesis and at the end of the growing season after harvesting. In the field with irrigation, the dynamics of the soil moisture at the rizosphere was determined by the thermogravimetric method, and the moisture content was maintained at 70–75 % of the water-retaining capacity.

During sprouting phase there was no remarkable difference in soil moisture between tillage practices and fertilization regimes but difference was merely observed by seasonal influence (Figure 1A). Soil moisture was different between irrigation and rain-fed practices during anthesis and harvesting phases, especially of 2006 and 2008 (Figures 1B, 1C). In average soil moisture was higher in irrigation cropping in 2008 during anthesis and harvesting phases. Irrigation diminished differences of soil moisture under applied tillage practices. The N content has decreased during vegetation, down to harvesting phase (Figures 2B and 2C): in higher degree in irrigation cropping (on average 33.29 kg N ha^{-1}) compared to rain-fed cropping, as well as in no-till treatment (on average 17.0 kg N ha^{-1}), compared to conventional and reduced cropping. At the end of vegetation, the highest N amount was conserved in soil in rain-fed cropping of 2008, with accent on conventional tillage (on average 7% higher N content, in relation to other tillage treatments). The maize grain yield was 33% lower in rain-fed cropping of 2008 on average, but the best results were observed with conventional tillage practice: 34% higher to reduced and 2 times higher to no-till practice. Only in year with highest precipitation level of 2007, such difference between tillage practices was diminished. Under irrigation differences in maize grain yield were insignificant between cropping years and fertilization regimes. Only in F1 the lowest yield was acquired, where low N level in soil wasn't enough.

Introduction

Toward agro-ecosystem protection, and sustainability, crop cultivation systems that heavily reduce soil fertility by outtake of nutrients with the yield, should been improved. The primary task of soil tillage is to maintain or improve favourable soil atributes (quality, fertility) and to prevent adverse changes (structure degradation, climate sensitiveness) (Birkas, 2009). The contemporary agricultural cropping practices underline that different tillage systems differently affect the soil fertility and the maize yield (Videnović, et al., 2007; Videnović, et al., 2011). Due to a climatic fluctuations and extreme conditions, it is necessary to maintain carefully soil water reserves. Special attention is given to irrigation cropping (Boţ ić, et al., 2007), irrespective to fact that rain-fed cropping is still the most broadly applied cultivation practices in the world, including about 1.13 billion ha, according to GMRCA (global map of rainfed cropland areas) data (Biradar, et al., 2006). The water amount of the soil and its water availability depends on soil properties and predominating farming systems.

Agricultural productivity and soil properties such as fertility, can be improved, restored, and maintained by the correct use of fertilizer (Šimansky and Tobiašova, 2010). Soil fertility is in high degree dependable on the application of nitrogen fertilizers, providing high plant yielding. The N-fertilisers play a role in environmental impacts, such as eutrophication and global warming. Some production models, including CERES, can be used for reducing N leaching without influencing a potentially high yield (Fang, et al., 2008). Tillage practice could partially conserve the soil moisture during relative dry periods (Jokela and Randall, 1989), as well as had positive impact on the N conservation (Omonode, et al., 2006; Sainju, et al., 2006) and grain yield (Tolimir, et al., 2001).

The aim of this study was to investigate different tillage systems: conventional, reduced and no-till, including effects of different fertiliser levels on changes of the soil N content and the maize yield in rain-fed and irrigation cropping practices.

Material and methods

Field experiments were conducted during the period 2005 – 2008 at the Maize Research Institute, Zemun Polje, in the vicinity of Belgrade (44°52'N 20°20'E). The soil was slightly calcareous chernozem with 47 % clay and silt and 53 % sand. The 0 – 30-cm layer had 3.3 % organic matter, 0.21 % total N, 1.9 % organic C, 14 and 31 mg per 100 g soil of available P and extractable K, respectively, 9.7 % total $CaCO_3$ and pH 7.8. The winter wheat was the preceding crop. Meteorological data (Table 1) show that 2008 was the driest year, with highest average temperature of 19.6 °C, while highest precipitation level was observed during season of 2007 (396.6 mm) and lowest average temperature was in 2005, about 1.7 °C lower to 2008.

Table 1. Average daily temperatures and precipitation sum during growing seasons of 2005, 2006, 2007 and 2008

Year	Months							$\overline{X}$ - Σ
	IV	V	VI	VII	VIII	IX	X	
Temperature (°C)								
2005	12.4	17.6	20.1	22.4	20.6	19.5	12.4	17.9
2006	13.4	16.9	20.0	23.7	20.2	18.5	14.3	18.1
2007	13.8	18.9	23.1	25.0	23.8	15.7	11.2	18.8
2008	14.1	19.3	22.8	23.6	24.3	17.4	15.6	19.6
Precipitation (mm)								
2005	28.2	3.2	65.0	44.0	64.0	21.4	22.1	247.9
2006	19.4	15.2	57.8	12.8	137.0	43.0	26.5	311.7
2007	11.0	52.6	87.0	18.9	51.6	73.0	102.5	396.6
2008	27.3	39.7	36.3	42.6	19.7	55.4	10.5	231.5

The four-replicate trial was set up under two cropping practices: rain-fed conditions and irrigation. The pre-sowing preparation considered three treatments: conventional tillage, reduced tillage and no-till, including also the application of three fertilisation levels:

1. without fertilisation - F1;
2. 150 kg N, 105 kg P_2O_5, 75 kg K_2O_5, ha^{-1} - F2;
3. 300 kg N, 211 kg P_2O_5, 150 kg K_2O ha^{-1} - F3;

The hybrid ZP SC 704 was hand sown on the 11th, 24nd, 6th and 8th April in each year by the block system, at the sowing density of 60,600 plants ha^{-1}.

Soil samples were taken during the three most important vegetative stages: about 30 days after sowing (May 11, 2005, May 24, 2006, May 5, 2007 and May 8, 2008), at anthesis (July 12, 2005, July 31, 2006, July 23, 2007 and July 25, 2008) and at the end of the growing season after harvesting (October, 13, 2005, October 20, 2006, November 22, 2007 and October 21, 2008). Differences between the sampling times were emphasised by different climatic conditions characteristic for the experimental years. The soil was sampled from the effective rizosphere zone, from the 0-30-, 30-60- and 60-90-cm layers. Average samples were used to determine the ammonium (NH_4) and nitrate (NO_3) from 1 M NaCl + 0.1 M $CaCl_2$ extracts by the method of Scharpf and Wehrmann (1975). Their sum was expressed as the mineral N.

In the field with irrigation, the dynamics of the soil moisture at the rizosphere was determined by the thermogravimetric method, and the moisture content was maintained at 70–75 % of the water-retaining capacity (Lal, 1976) by providing water from a rain gun (BAUER RAIN STAR). Since that irrigation was performed from the phase of maize intensive growth to the end of grain filling, according to adequate quantity of precipitation present during this period during 2005 there was no requirement for irrigation, while during 2006, 2007 and 2008 irrigation was provided with norms observed in Table 2.

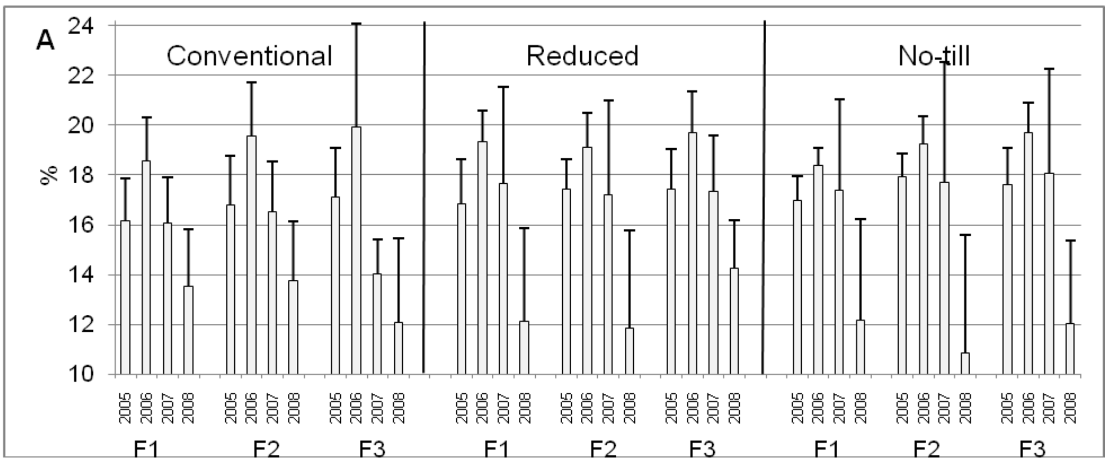
Table 2. Irrigation norms (mm) during growing seasons of 2006, 2007 and 2008 (there was no requirement for irrigation during 2005)

	2006	2007					2008		
Date	21.07.	19.07.	26.07.	02.08.	Σ		09.06.	04.07.	Σ
Conventional	50	50	50	50	150		17.8	20	37.8
Reduced	30	40	50	50	140		15.7	20	35.7
No-till	40	30	50	50	130		15.4	20	35.4

The data on soil moisture and N level were presented with standard deviation, while data on the grain yield, depending on the investigated factors, were statistically processed by the analysis of variance (ANOVA) and were analysed by the LSD-test.

Results and discussion

During sprouting phase there was no remarkable difference in soil moisture between tillage practices and fertilization regimes but difference was merely observed by seasonal influence (Figure 1A). The highest values of soil moisture were present in 2006 under all three applied tillage practices (on average 3.49 – 4.23% higher to other seasons). The lowest values of soil moisture were present in 2008, as season with the relative high average temperatures during April and May, irrespective to high amounts of precipitations (Table 1).



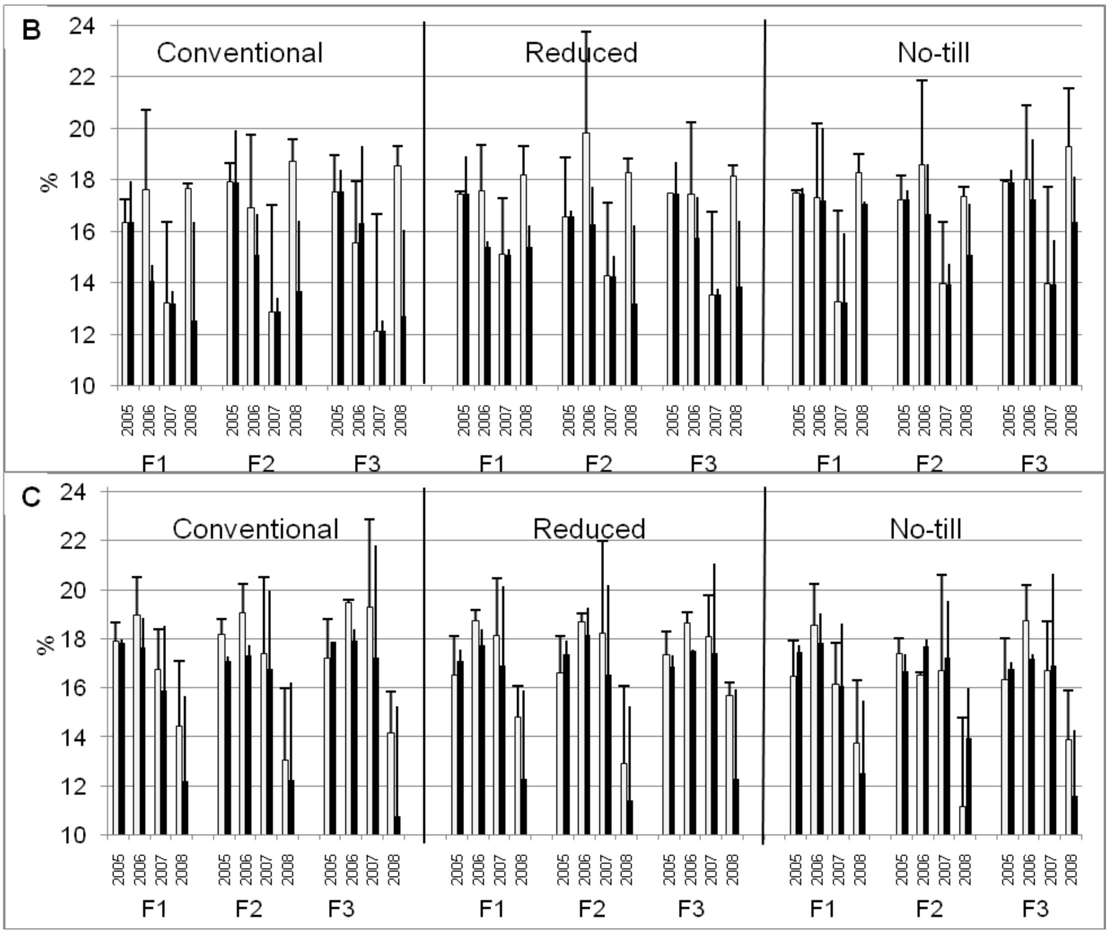


Figure 1: The influence of cropping season, irrigation, tillage practice and fertilization level (F1, F2 and F3) on soil moisture during A - sprouting phase; B – anthesis; C - harvesting (□-Irrigation; ■-Rain-fed)

Soil moisture was different between irrigation and rain-fed practices during anthesis and harvesting phases, especially of 2006 and 2008 (Figures 1B, 1C). In average soil moisture was higher in irrigation cropping in 2008 during anthesis and harvesting phases up to 3.83% and 1.63%, respectively. When we take into consideration the tillage practices, soil moisture was slightly higher during anthesis (on average 1.17%) under no-till in rain-fed cropping in relation to conventional and reduced tillage, similar to results of Lal (1976). Meanwhile, irrigation diminished differences of soil moisture under applied tillage practices.

Irrespective to differences in N content, present in observed cropping seasons during sprouting phase, the N content increased by fertilization level, on average from 304.66 kg N ha^{-1} in F1, up to 481.11 kg N ha^{-1} in F3 (Figure 2A). The N content has decreased during vegetation, down to harvesting phase (Figures 2B and 2C): in higher degree in irrigation cropping (on average 33.29 kg N ha^{-1}) compared to rainfed cropping, as well as in no-till treatment (on average 17.0 kg N ha^{-1}), compared to conventional and reduced cropping, opposite to results of Sainju et al. (2006). It was interesting to underline that lowest variations in N content between, seasons, applied fertilization regimes and irrigation during anthesis were present in conventional tillage, while at the end of vegetation, the highest N amount was conserved in soil in rain-fed cropping of

2008 (on average 48% higher to other experimental seasons), with accent on conventional tillage (on average 7% higher N content, in relation to other tillage treatments). The obtained results were in agreement with data of Jokela and Randall (1989) about affected N uptake during dry season.

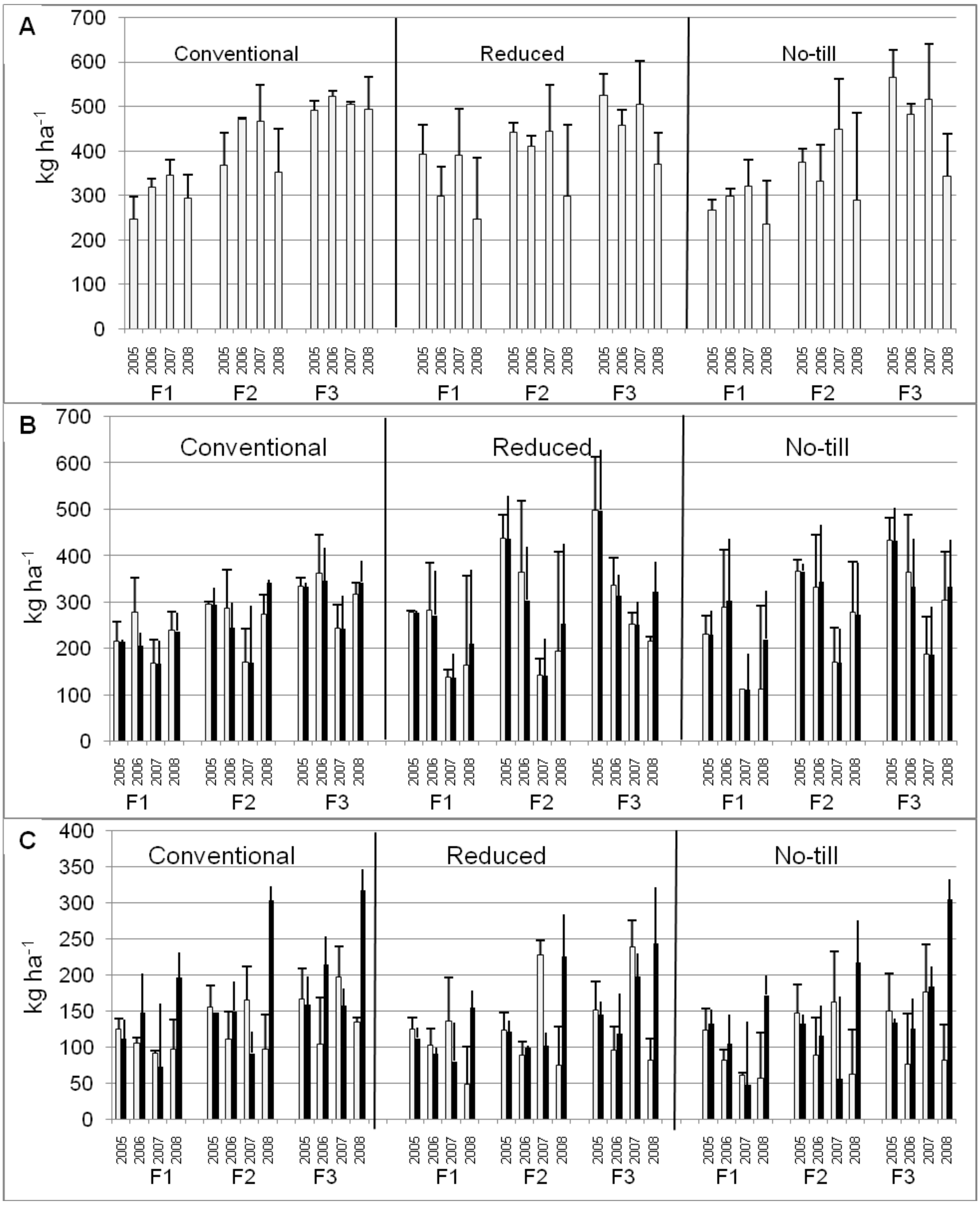


Figure 2: The influence of cropping season, irrigation, tillage practice and fertilization level (F1, F2 and F3) on soil N status A - sprouting phase; B – anthesis; C – harvesting (□-Irrigation; ■-Rain-fed)

The maize grain yield was 33% lower in rain-fed cropping of 2008 on average, (Table 3), indicating poorer utilization of soil N in dry conditions (López-Bellido, et al., 2000). In such dry season, best results of grain yield were observed with conventional tillage practice: 34% higher to reduced and 2 times higher to no-till practice, confirming previously presented results (Tolimir, et al., 2001; Videnović, et al., 2011). Only in year with highest precipitation level of 2007, such difference between tillage practices was diminished. Under irrigation differences in maize grain yield were insignificant between cropping years and fertilization regimes. Only in F1 the lowest yield was acquired, where low N level in soil wasn't enough. Generally, the irrigation express positive effect on grain yield achieving in all three tillage practices and four seasons (21% higher yield), compared to rain-fed cropping, indicating importance of irrigation (Boţ ić et al., 2007). This trend was opposite in 2005, as season where there was no necessity for application of irrigation and even 5% higher yield was achieved under reduced tillage in rain-fed cropping, compared to irrigation.

Table 3: The influence of different tillage and fertilization level (F1, F2 and F3) on grain yield in 2005, 2006, 2007 and 2008

		Irrigation					Rain-fed				
		2005	2006	2007	2008	$\overline{x}$	2005	2006	2007	2008	$\overline{x}$
Convent.	F1	13.18	10.54	10.86	10.69	11.32	13.13	10.08	5.72	9.64	9.64
	F2	14.53	13.51	11.88	12.20	13.03	13.80	13.51	8.57	10.27	11.54
	F3	15.68	15.06	13.00	12.99	14.18	13.92	12.72	9.10	8.78	11.13
	$\overline{x}$	14.46	13.04	11.91	11.96	12.84	13.61	12.10	7.80	9.57	10.77
Reduced	F1	10.51	11.74	11.11	7.88	10.31	10.87	9.29	5.85	3.41	7.35
	F2	12.20	12.68	12.75	9.33	11.74	12.35	10.84	9.20	8.37	10.19
	F3	12.62	13.23	11.91	11.61	12.34	13.95	12.15	8.23	7.17	10.38
	$\overline{x}$	11.78	12.55	11.92	9.60	11.46	12.39	10.76	7.76	6.32	9.31
No-till	F1	6.69	8.98	7.70	3.55	6.73	5.90	5.49	6.48	2.25	5.03
	F2	12.41	12.16	11.15	6.57	10.57	6.93	7.76	7.22	4.54	6.61
	F3	12.86	13.56	11.97	8.47	11.72	14.70	10.67	6.22	5.01	9.15
	$\overline{x}$	10.65	11.57	10.27	6.20	9.67	9.18	7.97	6.64	3.94	6.93
LSD 5%		Year 3.58	Tillage 3.46	Fertilization 2.83			Year 6.71	Tillage 2.42	Fertilization 3.32		

Based on the data obtained in this research, it could be concluded that the irrigation settled soil moisture to the similar level between tillage practices. In rain-fed cropping only no-till induced increase of soil moisture during anthesis. The highest N amount in soil remained under conventional tillage in rain-fed cropping of 2008, compared to irrigation, indicating poorer utilization of soil N in dry conditions. Additionally, the highest grain yield was observed with conventional tillage practice, while high precipitation level of 2007 diminished difference between tillage practices. Moreover, irrigation diminished differences between cropping years and fertilization regimes, with exception present in F1, where low N level in soil wasn't enough to acquire normal yield.

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