THE INFLUENCE OF SOIL TILLAGE AND NITROGEN FERTILIZATION ON MINERAL NUTRITION OF MAIZE

Gheorghe Petcu, Elena Petcu, Gheorghe Sin and Ioana Chirnogeanu [1]

ABSTRACT

The paper presents aspects regarding some changes of physical and chemical soil properties in a long term experiment with different tillage methods. Also, some aspects regarding nitrogen and phosphorus metabolism in maize were investreated. The results shown that bulk density, soil porosity, soil aired porosity, distribution and nitrate and phosphorus content of soil were modified in disked and no-tillage variants compared with ploughed variants. These soil modifications influenced negatively nitrogen and phosphorus uptake and distribution in maize plants and finally reduced the yields. The nitrogen applied as fertilizer in soil stimulated the nitrate reductase activity which was very significant correlated in first vegetation phases with the level of total nitrogen accumulation in leaves (r= 0.91*, r = 0.73**) and with yield (r = 0.77**, r = 0.81**).**

Key words: bulk density, maize, N and P content, soil porosity, tillage method.

INTRODUCTION

The mineral nutrient needed in the greatest abundance by plants is nitrogen, because this is the main constituent of proteins and nucleic acids (Rusu and Ştefanic, 1990).

However, plants must compete for nitrogen in the soil with abiotic and biotic processes such as erosion, leaching, microbial consumption, etc. Soil nitrogen is also lost when crops are harvested and plant material is removed from the soil. To be competitive, plants have developed several mechanisms to acquire nitrogen at low concentrations and to use a variety of forms of nitrogen. Plants can assimilate inorganic forms, such as nitrate and ammonia, and organic forms, such as urea (Crawford, 1995).

After nitrate uptake from the soil, the next step in the nitrogen assimilation pathway is nitrate reduction to nitrite. The enzyme that catalyzes this reaction is nitrate reductase (NR) (Rufty et al., 1986; Fedorova et al., 1994). In fact, the NR activity indicates the nitrogen metabolism in plant (Vaughn and Campbell, 1988)

Information on nitrogen and phosphorus accumulation and redistribution patterns in maize under soil tillage systems are necessary to maximize yield and improve nitrogen and phosphorus use efficiency (Marshner, 1995).

In order to obtain higher maize yield, one has to take into account the soil-plant relationship, plant demands for water, nutrients, temperatures, light, oxygen, etc. and also all soil and plant processes which are influenced by soil tillage. So, the aim of this paper was to analyse the influence of different soil tillage and mineral fertilization on mineral nutrition of maize.

MATERIALS AND METHODS

The study was conducted on a cambic cernozem soil of Fundulea in a long term experiment (initiated in 1980) under rainfed conditions.

Fundulea 376 hybrid was sown at April 25, 1996 at 45000 plants/ha.

Tillage methods were autumn plowing (conventional tillage), spring plowing, disked in autumn and before sowing and no-tillage. These tillage methods were initiated in 1981.

The plots were fertilized with 60 kg N/ha (one variant) and 120 kg N/ha (the other variant). All variants were fertilized in autumn with 75 kg P_2O_5/ha.

The nitrate reductase activity was determined following Ştefanic method (1972) at 4-6 leaves, 8-10 leaves and silking stage.

The total nitrogen was determined by Kjeldahl method, total phosphorus of leaves by spectrophotometrical method with vanadate.

The classical agrochemical method were used for soil total nitrogen and phosphorus content.

[1] Research Institute for Cereals and Industrial Crops. 8264 Fundulea., Romania

RESULTS AND DISCUSSIONS

Before showing some aspects of mineral nutrition of maize plants let us follow the evolution of the main physical and chemical indicators of the soil between 1981-1996 (Table 1).

In the ploughed variants, the soil porosity and aired soil porosity were similar from 0 to 40 cm and the bulk density increased from 1.17 g/cm^3 in the superficial layer to 1.41 g/cm^3 into soil depth (40 cm) for ploughing in autumn and from 1.25 g/cm^3 to 1.47 g/cm^3 for ploughing in spring. In disked and no-till variants the soil was more compacted: the bulk density increased as compared to ploughed variants, the soil porosity was slowly affected but the aired soil porosity was diminished in superficial layer and increased into the depth (30-40 cm) (Table 1).

The concentration of nitrate in the soil was very low and uniform in the ploughed in autumn variant from 0 to 40 cm compared to all the other variants. So, no-till and the disked system conducted to a higher nitrate concentration in superficial layers of soil (Table 2).

Regarding phosphorus concentration, our results showed significant differences between soil layers analysed and soil tillage methods. So, in all variants in the base profile analysed (35-40 cm) phosphorus concentration was very low as comparing with superficial layers from disked and no-tillage treatment (Table 3).

Table 1. The effect of soil tillage methods on the main physical indicators of the soil (before sowing). Fundulea 1981-1996

Indicators	Soil tillage methods	Depth of soil (cm)			
		0-10	10-20	20-30	30-40
Bulk density (g/cm^3)	Ploughing in autumn	1.17	1.38	1.40	1.41
	Ploughing in spring	1.25	1.40	1.43	1.47
	Disked	1.26	1.41	1.54*	1.50
	No-tillage	1.37*	1.46	1.54*	1.48
	LSD 5%	0.15	0.14	0.12	0.13
Soil porosity (%)	Ploughing in autumn	50.4	45.8	46.9	47.1
	Ploughing in spring	50.5	47.8	47.1	46.9
	Disked	48.1	44.8	46.9	46.7
	No-tillage	48.1	45.5	47.2	47.8
	LSD 5%		2.4		
Aired soil porosity (%)	Ploughing in autumn	17.1	7.5	9.2	6.5
	Ploughing in spring	17.2	10.9	9.6	8.2
	Disked	13.2	5.9	9.2	7.7
	No-tillage	14.8	6.9	9.7	9.7
	LSD 5%		4.1		

Table 2. Concentration of nitrate in the soil, one month later after sowing (ppm, $N\text{-}NO_3$)

Rate of nitrogen fertilization (Factor A)	Soil tillage methods (Factor B)	Depth of soil (cm)							
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
60 kg N/ha	Ploghing in autumn	3.04^{000}	2.09^{000}	1.86^{000}	1.88^{000}	2.38^{000}	2.32^{000}	2.4^{000}	1.9^{000}
	Ploghing in spring	14.8***	6.23	6.58	7.02	8.5**	10.2**	8.7**	7.08
	Disked	12.2***	4.78	3.31^{000}	3.05^{000}	3.39^{000}	3.68^{00}	4.75^{0}	4.5^{000}
	No-tillage	26.7***	8.5**	8.15*	7.13	6.38	6.6^{0}	6.56	6.27
		LDS 5%(for two factors) = 1.58							
120 kg N/ha	Ploghing in autumn	2.87^{0}	2.55^{00}	2.76^{0}	2.93^{0}	2.23^{00}	2.47^{00}	2.13^{00}	2.03^{00}
	Ploghing in spring	12.27***	6.92	6.42	8.31	7.02	8.59	7.43	7.48
	Disked	5.77	4.46	3.35^{0}	3.33^{0}	3.8^{00}	2.97^{0}	2.93^{0}	2.03^{0}
	No-tillage	19.87***	13***	10.1**	11.2**	10.8**	10.2**	8.25	7.63
		LDS 5% (for two factors) = 2.56							

Table 3. Concentration of phosphorus in the soil, one month later after sowing (ppm)

Rate of nitrogen fertilization (Factor A)	Soil tillage methods (Factor B)	Depth of soil (cm) 0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
60 kg N/ha	Ploughing in autumn	42.40	42.40	40	45.73	50.80	45.20	25.13	9.2
	Ploughing in spring	30.26	31.33	30.93	31.60	25.86	18.73	6.53	5.40
	Disked	103.13	77.26	19.13	12.33	11.40	8.40	5.66	5.46
	No-tillage	124.6	64	26.45	18.26	9.10	6.33	6.26	5.73
	LDS 5%(for two factors) = 7.90								
120 kg N/ha	Ploughing in autumn	59.33	44.46	42.93	57.33	58.20	52.66	22.66	7.33
	Ploughing in spring	32.13	30.80	32.40	36.40	38	26.63	14.53	6.86
	Disked	98.87	57.33	13.86	11.26	10.80	8.06	7.46	7.13
	No-tillage	124.33	75.6	41.66	27.66	20.06	10	6.73	5.73
	LDS 5% (for two factors) = 8.25								

Now, let follow how the modification of the main physical and mineral properties of the soil presented above can influence the plants.

Soil tillage methods influenced nitrate and phospohorus level from leaves. The level of phosphorus uptake is normally (0.3-0.5 % for 100 g dry matter) except in plants from disked and no-till variants fertilized with more nitrogen (Figure.1).

The phosphorus requirement for optimal growth ranges from 0.3-0.5 % of the plant dry matter during the stage of growth (Marshner, 1995).

It is obvious that in variants mentioned above there was phosphorus deficiency.

Morphological charaters such as root length, surface area or intensity of root hairs are constituents of strongly phosphorus uptake (Eissenstat, 1992, cited by Otani and Ae, 1996) because soil phosphorus is supplied to plants mainly by diffusion (Claasen, 1990, cited by Otani and Ae, 1996) and the phosphorus diffusion coefficient is very low (Barber, 1984 cited by Otani and Ae, 1996).

The effect of nitrogen rate fertilization was insignificant but the age of plants and soil tillage influenced significant the total nitrogen level as shown by data from figure 2. The higher content of total nitrogen was registered in earlier stage of growing and in ploughed variants.

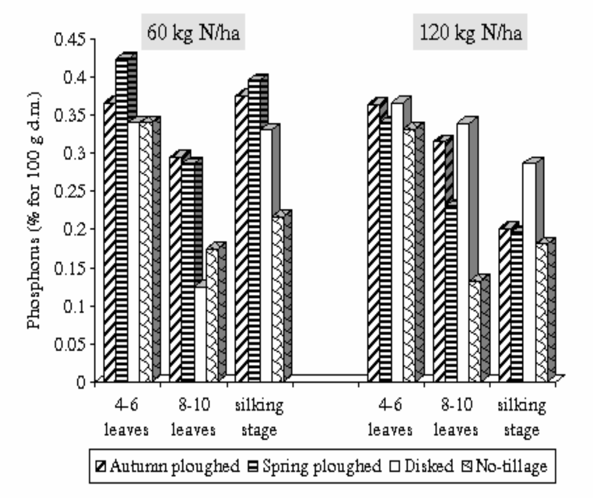

Figure 1. Phosphorus content in plants
LSD 5%: for 4-6 leaves = 0.037;
for 8-10 leaves = 0.042;
for silking stage = 0.032

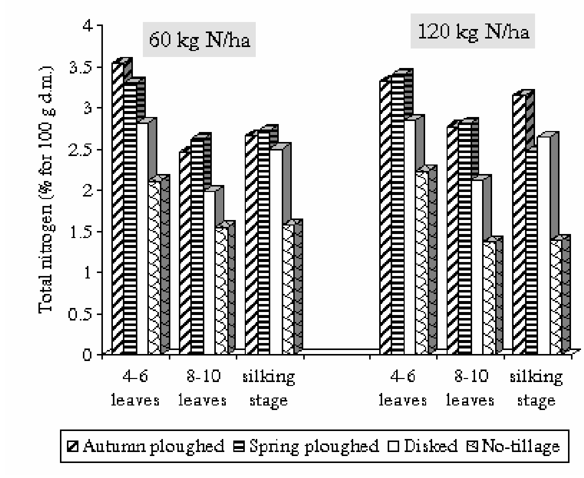

Figure 2. Total nitrogen from maize plants
LSD 5%: for 4-6 leaves = 0.037;
for 8-10 leaves = 0.042;

for silking stage = 0.032

In a similar experience, Ţerbea et al. (1994) showed that sever soil compaction determines both the diminution of the biomas accumulation in the roots and the grain yield per plant.

ANOVA analyses for nitrate reductase activity in maize leaves indicated a significant influence of plant age, soil tillage systems and a very significant influence of nitrogen fertilization for earlier stage of vegetation (Table 4).

Table 4. Values of F factors (Anova analyses) for nitrate reductase activity in maize plants

Source of variance	DF	F values (4-6 leaves)	F values (8-10 leaves)	F values (silking stage)
Soil tillage	3	30.157***	63.818***	6.071**
Error	6			
Rate of nitrogen fertilization	1	0.793	43.330***	0.686
Interaction	3	2.361	2.693	6.118*
Error	8			

The highest activity of nitrate reductase occured when the maize plants were young (4-6 leaves). In the silking stage, the nitrate reductase activity declines rapidly, more in leaves of plants grown in no-tillage variant than in plaughed ones (Figure 3).

The nitrogen applied as fertilizer in the soil stimulated the nitrate reductase activity in the earlier vegetation stage.

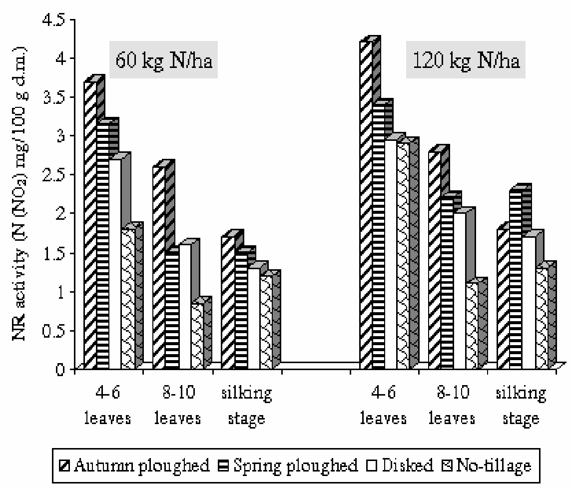

Figure 3. Nitrate reductase activity in different vegetation stages of maize

Nitrate reductase activity was positively correlated with the level of total nitrogen accumulation in the leaves (r = 0.91*** in 4-6 leaves stage; r = 0.73** in 8-10 leaves stage, Table 5). A significant correlation was found between yield obtained and nitrate reductase activity, too (r = 0,77**; r = 0.81**, Table 5).

Table 5. Relationship between nitrate reductase activity and total nitrogen content and yield

Specification	Nitrate reductase activity (4-6 leaves)	Nitrate reductase activity (8-10 leaves)	Nitrate reductase activity (silking stage)
Total nitrogen (4-6 leaves)	r = 0.91***		
Total nitrogen (8-10 leaves)		r = 0.73**	
Total nitrogen (silking stage)			r = 0.37
Yield	r = 0.77**	r = 0.81**	r = 0.45

All these modifications concernig physical soil indicators, level of nitrogen and phosphorus in soil and in plants influenced the level of maize yield, too. In 1996 the yields in disked and no-tillage variants were 18.6 q/ha and 16.4 q/ha respectively while than in ploughed in autumn variant were 26.8 (Figure 4).

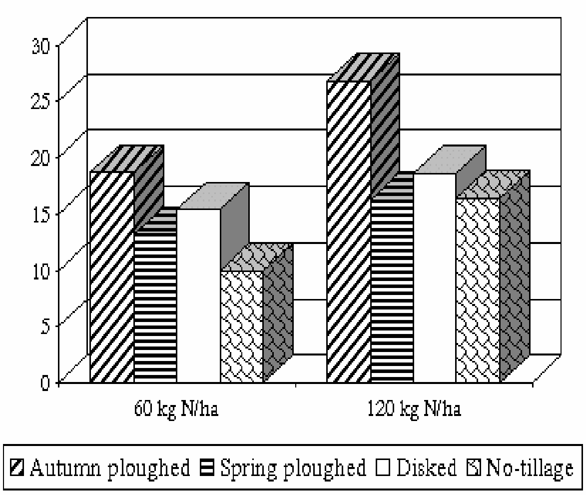

Figure 4. Effect of soil tillage method and nitrogen fertilization on maize yield . Fundulea, 1996

We must mention that in 1996 generally maize yield under rainfed conditions was affected by drought, too. In the same experiment in 1995 - year with normal precipitations in critical stage for water, the maize yield in ploughed variant was 56.5 q/ha (annual report of RICIC Fundulea).

CONCLUSIONS

In the case of minimum works applied to the soil (disking or no-tillage), bulk density increased, soil porosity and aired soil porosity were also modified and all these determined a soil compaction and a higher nitrate and phosphorus concentration in superficial layers of soil.

The phosphorus content of plants was normally except disked and no tillage variants fertilized with more nitrogen, where there was a phosphorus defficiency in the plants.

Nitrate reductase activity was influenced by the age of plants and soil tillage methods. The highest activity occured when the maize plants were young and in autumn ploughed variants.

Information on nitrogen and phosphorus accumulation and redistribution patterns in maize under soil tillage systems will be necessary to maximize and improve yield.

REFERENCES

Crawford, N., 1995. Nitrate: nutrient and signal for plant growth. The plant cell, vol.7:859-868.

Fedorova, E., Greenwood, J.S., and Oaks, A. 1994. In-situ localization of nitrate reductase in maize roots. Planta 194: 279-286.

Marshner, H. 1995. Mineral nutrition of higher plants. Academic press. Inc.London, San Diego, New York: 270-277.

Otani, T., and Ae, N., 1996. Sensitivity of phosphorus uptake to change in root length and soil volume. Agronomy J., 88: 371-375.

Rufty, T.W., Thomas, J.E., Remmler, J.L., Campbell, WH., and Volk, R.J., 1986. Intracellular localization of nitrate reductase in root. Plant physiol. 82: 675-680.

Ţerbea, M., SIN, G., Crăciun, I., Petcu, E., Petcu, G., 1994. Aspects of the development of the root system of the maize depending on certain factors from the soil. Romanian Agricultural Research, no.1: 45-53.

Vaughn, K.C and Campbell, W.H., 1988. Immunological localization of nitrate reductase in maize leaves. Plant physiol.88: 1354-1357.

Rusu, P., Ştefanic, G., 1990. Unele aspecte privind metabolismul azotului la porumb. Probl.agrofit.teor.aplic., XII (1): 43-69.

Table 1. The effect of soil tillage methods on the main physical indicators of the soil (before sowing). Fundulea 1981-1996.

Indicators	Soil tillage methods	Depth in soil			
		0-10	10-20	20-30	30-40
Bulk density (g/cm^3)	Plowing in autumn	1.17	1.38	1.40	1.41
	Plouwing in spring	1.25	1.40	1.43	1.47
	Disked	1.26	1.41	1.54*	1.50
	No-tillage	1.37*	1.46	1.54*	1.48
	LSD 5%	0.15	0.14	0.12	0.13
Soil porosity (%)	Plowing in autumn	50.4	45.8	46.9	47.1
	Plowing in spring	50.5	47.8	47.1	46.9
	Disked	48.1	44.8	46.9	46.7
	No-tillage	48.1	45.5	47.2	47.8
	LSD 5%		2.4		
Aired soil porosity (%)	Plowing in autumn	17.1	7.5	9.2	6.5
	Plowing in spring	17.2	10.9	9.6	8.2
	Disked	13.2	5.9	9.2	7.7
	No-tillage	14.8	6.9	9.7	9.7
	LSD 5%		4.1		

Table 2. Concentration of nitrate in the soil, one month later after sowing (ppm, $N\text{-}NO_3$)

Rate of nitrogen fertilization (Factor A)	Soil tillage methods (Factor B)	Depth soil (cm)							
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
60 kg N/ha	Plowing in autumn	3.04^{000}	2.09^{000}	1.86^{000}	1.88^{000}	2.38^{000}	2.32^{000}	2.4^{000}	1.9^{000}
	Plowing in spring	14.8***	6.23	6.58	7.02	8.5**	10.2**	8.7**	7.08
	Disked	12.2***	4.78	3.31^{000}	3.05^{000}	3.39^{000}	3.68^{00}	4.75^{0}	4.5^{000}
	No-tillage	26.7***	8.5**	8.15*	7.13	6.38	6.6^{0}	6.56	6.27
		LDS 5%(for two factors) = 1.58							
120 kg N/ha	Plowing in autumn	2.87^{0}	2.55^{00}	2.76^{0}	2.93^{0}	2.23^{00}	2.47^{00}	2.13^{00}	2.03^{00}
	Plowing in spring	12.27***	6.92	6.42	8.31	7.02	8.59	7.43	7.48
	Disked	5.77	4.46	3.35^{0}	3.33^{0}	3.8^{00}	2.97^{0}	2.93^{0}	2.03^{0}
	No-tillage	19.87***	13***	10.1**	11.2**	10.8**	10.2**	8.25	7.63
		LDS 5% (for two factors) = 2.56							

Table 3. Concentration of phosphorus in the soil, one month later after sowing (ppm)

Rate of nitrogen fertilization (Factor A)	Soil tillage methods (Factor B)	Depth soil (cm)							
		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40
60 kg N/ha	Plowing in autumn	42.40	42.40	40	45.73	50.80	45.20	25.13	9.2
	Plowing in spring	30.26	31.33	30.93	31.60	25.86	18.73	6.53	5.40
	Disked	103.13	77.26	19.13	12.33	11.40	8.40	5.66	5.46
	No-tillage	124.6	64	26.45	18.26	9.10	6.33	6.26	5.73
		LDS 5%(for two factors) = 7.90							
120 kg N/ha	Plowing in autumn	59.33	44.46	42.93	57.33	58.20	52.66	22.66	7.33
	Plowing in spring	32.13	30.80	32.40	36.40	38	26.63	14.53	6.86
	Disked	98.87	57.33	13.86	11.26	10.80	8.06	7.46	7.13
	No-tillage	124.33	75.6	41.66	27.66	20.06	10	6.73	5.73
		LDS 5% (for two factors) = 8.25							

Table 4. Values of F factors (Anova analyses) for nitrate reductase activity in maize plants

Source of variance	GF	F values (4-6 leaves)	F values (8-10 leaves)	F values (silking stage)
Soill tillage	3	30.157***	63.818***	6.071**
Error	6			
Rate of nitrogen fertilization	1	0.793	43.330***	0.686
Interaction	3	2.361	2.693	6.118*
Error	8			

Table 5. Relationship between nitrate reductase activity and total nitrogen content and yield

Specification	Nitrate reductase activity (4-6 leaves)	Nitrate reductase activity (8-10 leaves)	Nitrate reductase activity (silking stage)
Total nitrogen (4-6 leaves)	r = 0.91***		
Total nitrogen (8-10 leaves)		r = 0.73**	
Total nitrogen (silking stage)			r = 0.37
Yield	r = 0.77**	r = 0.81**	r = 0.45

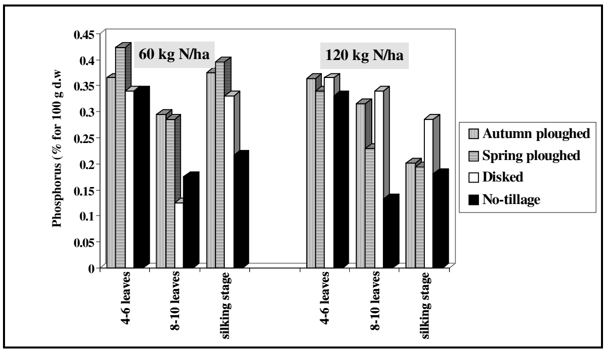

Figure 1. Phosphorus content in plants (% for 100 g d.w.). LSD 5% (for 4-6 leaves) = 0.037; LSD 5% (for 8-10 leaves) = 0.042; LSD 5% (for silking stage) = 0.032

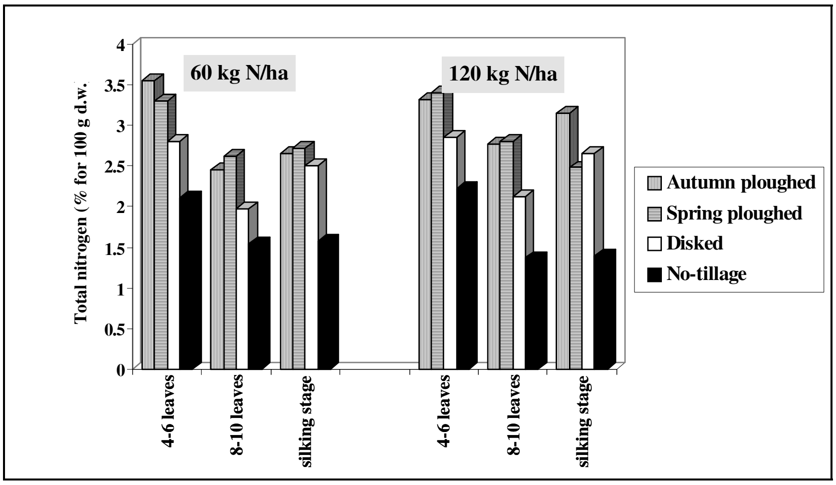

Figure 2. Total nitrogen from maize plants. LSD 5% (for 4-6 leaves) = 0.037; LSD 5% (for 8-10 leaves) = 0.042; LSD 5% (for silking stage) = 0.032

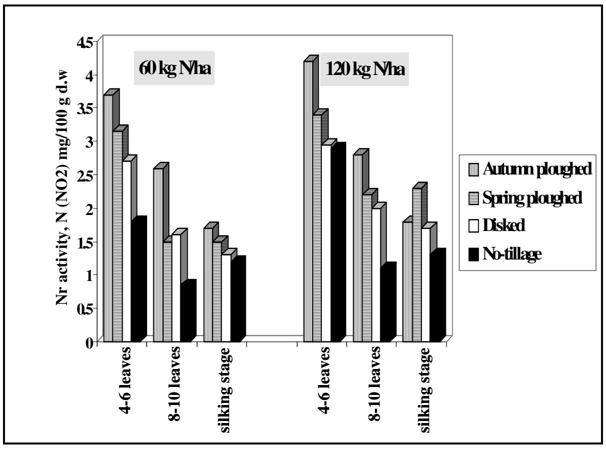

Figure 3. Nitrate reductase activity in different vegetation stage in maize

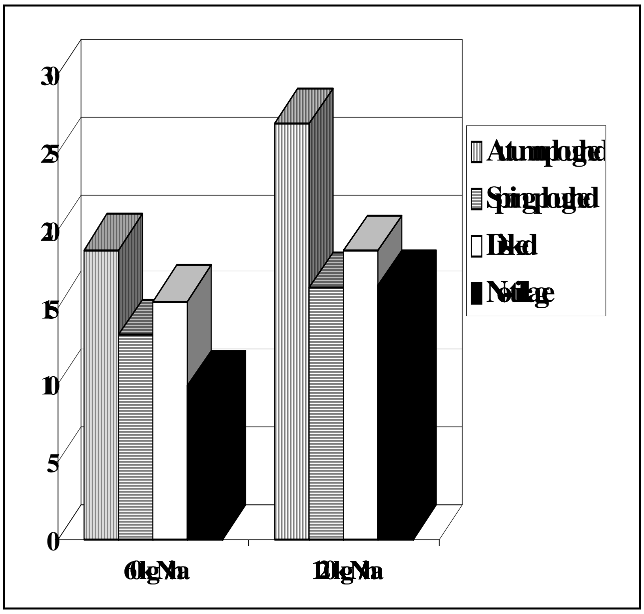

Figure 4. Effect of soil tillage method and nitrogen fertilization on maize yield - Fundulea, 1996