Macroelement and nitrate contents in maize leaves under different nitrogen fertilization

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Abstract

The aim of this research was to quantify the effect of fertilization with different nitrogen levels and different type of fertilizers in three developmental stages of maize plants (5 leaves, flowering and milk maturity). Five nitrogen levels (80 kg/ha; 120 kg/ha.; 160 kg/ha; 200 kg/ha and 240 kg/ha) and two type of nitrogen fertilizers (Ammonium nitrate and Urea) were applied in the experimental trials. The response of maize to the fertilization levels and type of fertilizers showed some influences on chemical content of maize leaves in different developmental stages. The total nitrogen and nitrates content increased at the same time with fertilization level, but the other chemical element contents (calcium, phosphorus pentoxide, calcium, potassium, magnesium) decreased when high quantities (240kg/ha) of fertilizers are used. Additionally, this study showed that the nitrates content was highest in the first development stage of plants, especially when ammonium nitrate fertilizer was used.

Abbreviations

ARDS of Suceava - Agricultural Research and Development Station of Suceava;
Ah –hydrolytic acidity;
Ap- Horizon A bio accumulative (layer);
Bv - Horizon B cambic;
Al- Exchangeable aluminium;
P-Al - Movable phosphorus;
K-Al - Movable potassium;
N- nitrogen
tN- Total nitrogen;
pH – (potential of hydrogen), is a scale used to specify the acidity or basicity of an aqueous solution).

Introduction

Nitrogen is an important element required for plant growth and development. It is a key component in many biological compounds that play a major role in photosynthetic activity and crop yield capacity (Cathcart and Swanton, 2003). Variation in nitrogen availability can affect plant development and grain production in maize. Maize grain yield is linked to both higher nitrogen uptake and higher ability to utilize nitrogen accumulated in the plant in yield production (Luque *et al*, 2006). Parameters such as leaf area index, longevity of leaf canopy and efficient use of incident light in maize are all increased by nitrogen (Muchow and Davis, 1988). An adequate supply of nitrogen in the soil, plant maintain their chlorophyll content for long time, which resulted in slower leaf senescence and moreover, plant is able to supply its seeds with nitrogen and photoassimilates for a longer period which results in higher yields (Eghball and Power, 1999).

As maize is a nitro-positive crop, the reduction in number of days taken for anthesis with increasing levels of nitrogen may be attributed to higher leaf area index and dry matter accumulation which results in increased vegetative growth and influenced anthesis (Martin *et al*, 1976). Application of higher dose of nitrogen produced maximum emergence in maize and also increased plant elongation and yield (Keskin *et al*, 2005; Siddiqui *et al*, 2006).

Al-Kaisi and Yin (2003) reported that nowadays the levels of nitrogen fertilizer used in the corn crop can be involved with the aquifer contamination or any type of natural resource, decreasing its quality. Also, some extra tools and agronomical practices can help the nitrogen efficiency (Cüi *et al*, 2009), such as using a narrow

row spacing, decreasing the fertilizer through increasing of recovery efficiency (Barbieri *et al*, 2008), crop rotation and the use of organic fertilizer, (Montemurro *et al*, 2006).

Weather and soil can contribute in the nitrogen (N) use efficiency in corn genotypes (Muchow 1998; Presterl *et al*, 2002). Thus, this study aimed to evaluate the presence of nitrates and of the other macroelements, at three developmental stages of the maize leaves, by chemical fertilization with two type of fertilizers (Ammonium Nitrate and Urea), in the climatic conditions of the Suceava Plateau, Romania.

Material and methods

The experiments were performed in the experimental field of the Maize Breeding Laboratory, within ARDS of Suceava, which is located in the Suceava Plateau, on a faeoziom soil. The experiment was designed two-factorial and placed according to the method of subdivided plots with the following graduations: factor a - fertilization levels with 6 graduations and factor b- two types of nitrogen fertilizers.

The maize genotype used in the experiment was the maize hybrid Suceava M. The trilinear hybrid Suceava M was created, by the team of breeders from ARDS of Suceava and homologated in 2019, well adapted in the Suceava Plateau, being from FAO range 200-280.

Agrochemical, the analyzed faeonziom soil has a strong acid reaction in both horizons (Ap - 4.75; Bt-4.98), a low nitrogen content, a moderate phosphorus content and a high potassium content. It is a medium fertility soil with acidic pH, suitable only for a certain variety of plants, such is maize crop.

Soil study site was a degraded faeonziom with high clay content. A chemical analysis performed one month before installing the trial indicated the following soil characteristics: Humus- 3,86 (%); clay - 27,96 %; P-Al- 53,2 ppm; K-AL 117 ppm; pH (water) 4,88; Nt (d.m.) -0,186 %; Al- 0,35 me/100g.

The two nitric fertilizers (Ammonium Nitrate and Urea) were applied after the emergence of the plants, using the following variants: V_1- unfertilized control; V_2 -N_{80}; V_3-N_{120}; V_4- N_{160}; V_5-N_{200}; V_6-N_{240}. The plot was maintained by manual work on rows and between rows. The plant samples were taken in three distinct periods: when the plants had 5 leaves, at flowering, and at maturing in milk.

Chemical analyses of soil and plants were performed by chemical and physico-chemical methods (Schollemberger method; Kacinscki method; colorimetric method).

Results and discussion

The impact of the two fertilizers (Ammonium nitrate and Urea) on different chemical elements (total nitrogen, phosphorus pentoxide, potassium, calcium, magnesium) and nitrates content in maize leaves at different development plant stages are presented. The content of the *total nitrogen* (tN) in maize leaves is presented in Table 1. It can be noticed that, when 240 kg/ha of both type of fertilizers is used, the content of tN in maize leaves resulted the highest at all plant developmental stages analysed in this research. When the highest quantities of fertilizers (240 kg/ha) were used, it was observed that the *phosphorus pentoxide* content (P_2O_5) was low in all development plant stages under study, with both types the addition of fertilizers. The lowest content of P_2O_5 is registered at milk maturity maize plant stage (Table1). Thus, the highest amounts of nitrogen caused a decrease in phosphorus pentoxide content in plant leaves.

The same situation was noticed in *potassium content* (Table 1). The *calcium* content in maize leaves, did not differ greatly in the six fertilization levels (from 0.2 to 0.9% in ammonium nitrate and 0.38 - 0.9% in urea). Also, very small calcium content on leaves at milk maturity stage (Table 1), was noticed. In the case of the *magnesium* content, differences both between the stages of development of the plants and the types of fertilizers were observed. At increasing nitrogen quantities, the magnesium content was decreasing, especially when high quantities of ammonium nitrate fertilizers were added (Table1).

The application of largest doses of Ammonium nitrate (240 kg/ha), led to a significant increase of *nitrates* content (502.7 ppm) in stage of 5 leaves, but decreased the contents of the other macro elements: *phosphorus pentoxide* (0,8% d.m), *potassium* (0,68% d.m), *calcium* (0,15%d.m) and *magnesium* (0,11%d.m) (Table1).

The application of highest doses of Urea (240 kg/ha), led to increases of *nitrates* content (163.1 ppm), during stage of 5 leaves, but not so strongly as when Ammonium nitrate was applied; on the other, but the other three macro elements: *phosphorus pentoxide* content decreases with 0,13%.d.m., *potassium content* with 0,98% *and magnesium* content with 0,08% d.m. On the other hand the *calcium* content increases at the maximum doses of Urea (240 kg/ha) with 0,05 % d.m (Table1).

During flowering period, the *nitrates* content in the leaves, is different function by the type of fertilizer and used doses. So the highest doses of Ammonium Nitrate led to increases of nitrates content with 334 ppm, but the same doses of Urea led to increases of

Table 1 - Chemical element contents in maize leaves at three plant development stages following different fertilization levels of Ammonium nitrate or Urea

Type of fertilizer	Fertilizer levels	Plant development stages		
		5 leaves	Flowering	Milk maturity
Total nitrogen contents (% d.m)				
Ammonium nitrate	Standard	2.43	1.89	0.97
	80kg/ha	3.36	2.31	1.62
	120 kg/ha	3.51	2.97	1.97
	160 kg/ha	3.97	3.19	2.41
	200 kg/ha	4.77	3.5	3.1
	240 kg/ha	5.62	4.2	3.57
Urea	Standard	2.31	2.07	0.83
	80kg/ha	3.97	2.67	1.11
	120 kg/ha	4.56	3.21	2.93
	160 kg/ha	4.78	3.86	3.27
	200 kg/ha	5.53	4.38	3.66
	240 kg/ha	6.08	5.11	4.09
Phosphorus pentoxide contents (% d.m.)				
Ammonium nitrate	Standard	0.48	0.41	0.32
	80kg/ha	0.42	0.37	0.3
	120 kg/ha	0.41	0.33	0.23
	160 kg/ha	0.38	0.22	0.22
	200 kg/ha	0.32	0.24	0.16
	240 kg/ha	0.34	0.23	0.18
Urea	Standard	0.43	0.39	0.33
	80kg/ha	0.41	0.31	0.26
	120 kg/ha	0.37	0.27	0.21
	160 kg/ha	0.36	0.25	0.17
	200 kg/ha	0.37	0.28	0.18
	240 kg/ha	0.33	0.26	0.16
Potassium contents (% d.m.)				
Ammonium nitrate	Standard	3.21	2.36	2.21
	80kg/ha	3.02	2.11	1.73
	120 kg/ha	1.98	1.97	1.33
	160 kg/ha	2.11	1.82	1.11
	200 kg/ha	1.87	1.63	1.17
	240 kg/ha	1.8	1.68	0.98
Urea	Standard	3.17	2.39	2.01
	80kg/ha	3.11	2.03	1.66
	120 kg/ha	3.07	1.72	1.43
	160 kg/ha	1.97	1.71	1.41
	200 kg/ha	1.83	1.63	1.08
	240 kg/ha	1.77	1.47	0.87
Calcium contents (% d.m.)				
Ammonium nitrate	Standard	0.87	0.79	0.23
	80kg/ha	0.66	0.53	0.24
	120 kg/ha	0.6	0.51	0.19
	160 kg/ha	0.67	0.48	0.23
	200 kg/ha	0.69	0.53	0.21
	240 kg/ha	0.72	0.66	0.21
Urea	Standard	0.9	0.83	0.43
	80kg/ha	0.81	0.8	0.4
	120 kg/ha	0.79	0.78	0.4
	160 kg/ha	0.82	0.8	0.39
	200 kg/ha	0.84	0.78	0.35
	240 kg/ha	0.86	0.77	0.36
Magnesium contents (% d.m.)				
Ammonium nitrate	Standard	0.33	0.3	0.21
	80kg/ha	0.25	0.21	0.19
	120 kg/ha	0.23	0.21	0.17
	160 kg/ha	0.23	0.17	0.11
	200 kg/ha	0.21	0.17	0.12
	240 kg/ha	0.2	0.16	0.1
Urea	Standard	0.36	0.31	0.28
	80kg/ha	0.34	0.26	0.26
	120 kg/ha	0.33	0.25	0.23
	160 kg/ha	0.3	0.23	0.21
	200 kg/ha	0.31	0.23	0.2
	240 kg/ha	0.28	0.21	0.2
Nitrates contents (ppm)				
Ammonium nitrate	Standard	375.2	283.2	187.2
	80kg/ha	437.2	402.3	281.3
	120 kg/ha	498.7	400.7	297.3
	160 kg/ha	687.3	552.9	358.2
	200 kg/ha	750.2	598.3	377.7
	240 kg/ha	877.9	617.2	397.8
Urea	Standard	368.7	296.1	162.1
	80kg/ha	398.2	317.9	177.9
	120 kg/ha	417.7	351.4	211.3
	160 kg/ha	467.1	372.2	267.7
	200 kg/ha	498.3	407.7	255.7
	240 kg/ha	531.8	417.8	296.4

Table 2 - Correlation coefficients between nitrate and other chemical elements contents in maize leaves following application of two type of fertilizers (Ammonium nitrate and Urea)

Ammonium nitrate fertilizer			Urea fertilizer		
Chemical elements from maize leaves	Nitrates contents (ppm)	Significance	Chemical elements from maize leaves	Nitrates Contents (ppm)	Significance
Total nitrogen (% d.m.)	0.944	***	Total nitrogen (% d.m.)	0.865	***
P_2O_5 (% d.m.)	0.025		P_2O_5 (% d.m)	0.455	*
K_2 (% d.m.)	0.042		K_2 (% d.m)	0.269	
Ca (% d.m.)	0.527	*	Ca (% d.m)	0.790	**
Mg (% d.m.)	-0.039		Mg (% d.m)	0.352	

nitrate content only with 121.7 ppm. The other macro elements content decreases, approximately with the same percentage at maximum doses, for both fertilizers (*phosphorus pentoxide* content decreases with 0.18% d.m. for Ammonium nitrate and 0.13% d.m. for Urea; *potassium content* decreases with 0.68% d.m. for Ammonium nitrate and 0.92% d.m. for Urea; *calcium* content decreases with 0.13%.d.m. for Ammonium nitrate and 0.06 % d.m. for Urea *and magnesium* content with 0,14 % d.m for Ammonium nitrate and 0.10 % d.m. for Urea) (Table1).

In the milk maturity development stage, the *nitrates* content in the leaves, is lower than the other plant development stages analyzed. So the highest doses of Ammonium Nitrate led to increases of *nitrates* content with 210.6 ppm, but the same doses of Urea led to increases of nitrates content only with 134.3 ppm. The other three macro elements content, were lower too (*phosphorus pentoxide, calcium and magnesium*). They decreases, approximately with the same percentage at maximum doses, for both fertilizers (*phosphorus pentoxide* content decreases with 0.14%.d.m. for Ammonium nitrate and 0.17% d.m. for Urea; *calcium* content decreases with 0.02%.d.m. for Ammonium nitrate and 0.07 % d.m. for Urea *and magnesium* content with 0,11 % d.m for Ammonium nitrate and 0.08 % d.m. for Urea). *Potassium* content, on the other hand, decreased more strongly in this phase of development (with 1.23 %.d.m. for Ammonium nitrate and 1.14% d.m. for Urea) (Table1)

In order to highlight the relationship between nitrates contents and the other chemical compounds from maize leaves correlation coefficients between nitrates content and the other chemical elements from maize plants, for those two types of fertilizers were calculated (Table 2). It was noticed very significant correlation coefficients between nitrates and total nitrogen contents with both types of fertilizers. In case of ammonium nitrate there is a significant correlation coefficient between *nitrates* and *calcium content* and respectively very significant correlation coefficients, in case of urea fertilizer (Table 2). Additionally, a significant correlation coefficient between *nitrates* and *phosphorus pentoxide* content, when it used Urea fertilizer, was observed.

The regression lines from graphics 1 and 2 emphasize the sense and intensity of correlations between analyzed traits.

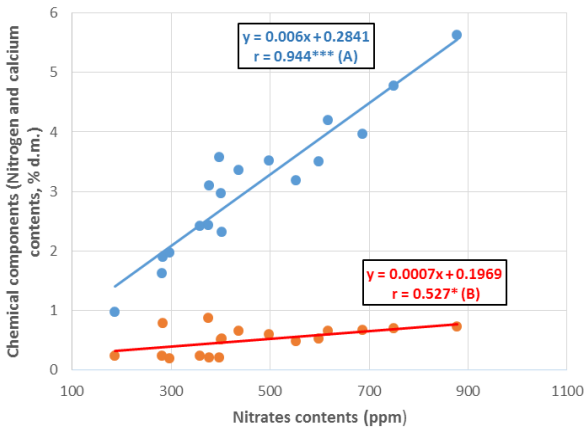

Fig. 1 - Regression lines between nitrates and two chemical components (nitrogen - A and calcium contents - B) in maize leaves, when it was used ammonium nitrate.

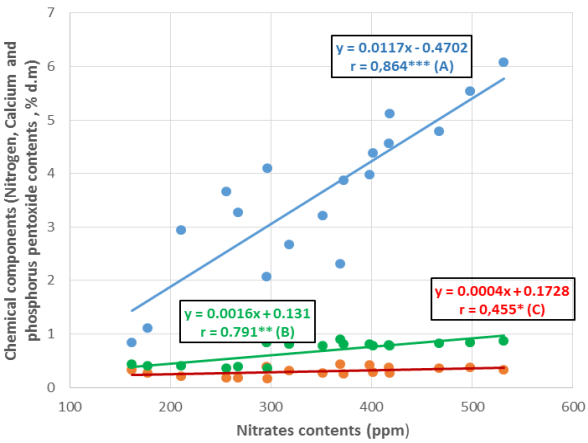

Fig. 2 - Regression lines between nitrates and three chemical components (nitrogen – A, calcium – B and phosphorus pentoxide contents - C) in maize leaves, when urea fertilizer was applied.

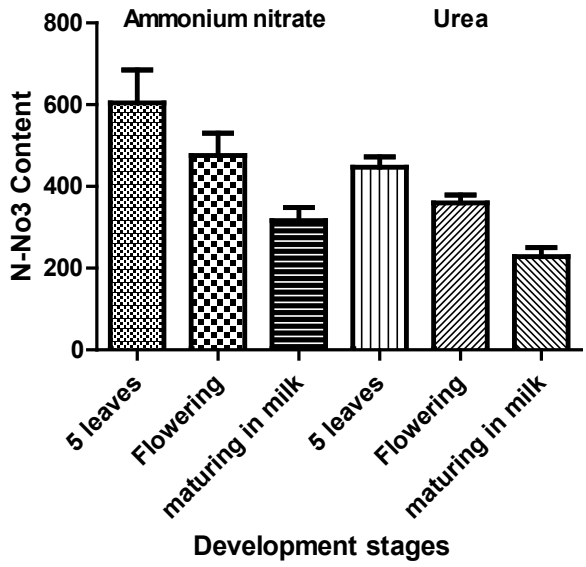

Fig. 3 - Plant Nitrate content at three development stages following two fertilizer (Ammonium nitrate and urea) application

In Figure 1 the relations between both *nitrates* and *nitrogen* and *calcium contents* are presented; when it was used ammonium nitrate, being very strong between *nitrates* and *nitrogen contents* (r=0.944***) and weaker between *nitrates* and *calcium* content, but statistically significant (r=0.527*).

In Figure 2 relationships between *nitrates* and three chemical components, when it was used urea fertilizer, are presented. In this case there is a very strong relation between *nitrates* and nitrogen contents (r= 0.864***), strong relation between *nitrates* and *calcium* contents (r=0.791**) and weaker one between *nitrates* and *phosphorus pentoxide* contents, statistically significant(r=0.455*).

In Figure 3, large differences between the two types of fertilizers used, were observed. In case of urea fertilizer the level of *nitrates* is smaller than in the case of ammonium nitrate fertilizer. Also, the *nitrates* content resulted highest in first plant development stage, especially when it was used ammonium nitrate fertilizer.

Conclusions

From this study it could be concluded that the fertilization levels and type of fertilizers have some influences on chemical content of maize leaves in different development stages.

If total nitrogen and nitrates content increase at the same time with fertilization level, the other chemical element contents (calcium, phosphorus pentoxide, calcium, potassium, magnesium) decrease when high quantities of fertilizers are used.

From statistical point of view, it was concluded that, when ammonium nitrate fertilizer was applied, the regression lines between nitrates and total nitrogen contents, respectively between nitrates and calcium contents showed correlations statistically significant. Instead, when urea fertilizer was used, relationships, between nitrates and nitrogen contents, respectively between nitrates and calcium contents and nitrates and phosphorus pentoxide contents, statistically significant were observed.

Regarding the levels of nitrates in maize leaves, it is observed that, the nitrates content is highest in the first development stage of plants, especially when ammonium nitrate fertilizer was used.

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References

Al-Kaisi MM, Yin X, 2003. Effects of Nitrogen Rate, Irrigation Rate, and Plant Population on Corn Yield and Water Use Efficiency. Agron J 95: 1475-1482.

Cathcart RJ, Swanton CJ, 2003. Nitrogen manage¬ment will influence threshold values of green foxtail (*Setaria viridis*) in corn. Weed Sci 51: 975-86.

Cui Z, Zhang F, Mi G, Chen F, Li F, Chen X, Li J, Shi L, 2009. Interaction between genotypic difference and nitrogen management strategy in determining nitrogen use efficiency of summer maize. Plant Soil 317: 267-276.

Eghball B, Power JF, 1999. Composted and non-composted manure application to conventional and non-tillage systems maize yield and nitrogen uptake. Agron J 91: 819-25.

Keskin B, Yilmaz IH, Turan N, 2005. Yield and quality of forage corn (*Zea mays* L) as influenced by cultivar and nitrogen rate. Agron J 4 (2): 138-41.

Luque S, Cirilo AG, Otegui ME, 2006. Genetic gains in grain yield and related physiological attributes in Argentine maize hybrids. Field Crops Res 95: 383-97.

Martin JH, Leonard WH, Stamp DL, 1976. Principles of Field Crop Production. Macmillan Publishing Co Inc.

Montemurro F, Maiorana M, Ferri D, Convertini G, 2006. Nitrogen indicators, uptake and utilization efficiency in a maize and barley

rotation cropped at different levels and sources of N fertilization. Field Crop Res 99: 114-124.

Muchow RC, Davis R, 1988. Effect of nitrogen sup¬ply on the comparative productivity of maize and sorghum in a semi-arid tropical environment. II. Radiation interception and biomass accumulation. Field Crops Res 18: 17-30.

Muchow, RC, 1998. Nitrogen utilization efficiency in maize and grain sorghum. Field Crop Res 56:209-216.

Presterl T, Groh S, Landbeck M, Seitz G, Schmidt W, Geiger HH, 2002. Nitrogen uptake and utilization efficiency of European maize hybrids developed under conditions of low and high nitrogen input. Plant Breed 121: 480-486.

Siddiqui MH, Oad FC, Jamro GH, 2006. Emergence and nitrogen use efficiency of maize under different tillage operations and fertility levels. Asian J Plant Sci 5 (3): 508-10.