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EFFECT OF AMMONIUM FERTILIZATION BY CULTAN METHOD ON DRY MATTER ACCUMULATION AND DYNAMICS OF NITROGEN UPTAKE BY MAIZE

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Abstract

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The aim of this trial was to assess the influence of nitrogenous fertilization by CULTAN (Controlled Uptake Long Term Ammonium Nutrition) method on the dynamics of above-ground biomass dry matter accumulation, dynamics of nitrogen reception and the content of macro elements in all plants in the phase BBCH 89 (fully ripe) of maize (*Zea mays* L.) in the Czech Republic conditions. In three-year small-plot field trial, two methods of nitrogen fertilization were used: conventional surface fertilization with calcium ammonium nitrate before sowing and local fertilization injection by the vegetation height of 20 cm by CULTAN method. By local application of ammonium ion, saturated space with diffusional gradient is created in the soil – so called depot, in which the ammonium ion is stable, but in an acceptable form for plants. Plants fertilized by this method reached comparable or slightly higher contents of dry matter. No positive effect of CULTAN method was proved on the occurrence of maize diseases. There was, however, a positive effect of adding sulphur into the fertilizer on the uptake of nitrogen in early phases of the maize development, by injection fertilized treatment. The contents of macro elements (P, S, Ca, Mg, K) in the whole plants in the phase BBCH 89 were comparable between conventional and CULTAN treatments, and at the station with lower precipitation there was a higher content of Ca and K.

Key words: calcium, CULTAN depot, injection, phosphorus, nitrification

Introduction

The principle of CULTAN (Controlled Uptake Long Term Ammonium Nutrition) consists in the location of liquid nitrogenous fertilizers containing a significant proportion of nitrogen in the ammonium form, near the root system so that the needed nitrogen is offered in the form accessible for plants and simultaneously less mobile in the soil (Weimar, 2003).

By this method, a fertilization solution rich in ammonium nitrogen is injected by special injection technology 7-20 cm deep into the soil near the roots. By local application of NH_4^+ saturated space with diffusion gradient is created in the soil – so called depot (Boelcke, 2003). The ammonium ion is very stable in these depots (Sommer, 2005), because in the internal parts of the depot the concentration of nutrients for the activity of nitrification bacteria is too high (Walter, 2003). By fertilization through CULTAN method, the ammonium nitrogen is received only in the roots, which have grown up to the edge of the depot, which hinders the phytotoxic effect of ammonia. These roots sprout intensively and concentrate round the depot's edge and during the plant's vegetation the roots move from the outer edge of the depot inwards (Balík et al., 2007). The received ammonia is in the roots bound to amino acids, which may be removed from the roots and the bottom part of the stem right to the growth spot, which results in better development of the root system. The production of cytokinins in the root tips increases at the expense of auxins and gibberellins in the sprouts (Marschner, 1995; Sommer and Scherer, 2007). That is why the root system by CULTAN plants is well developed. Moreover, cytokinins influence the formation of cells in the endosperm of the grain and therefore they have an effect on the grain size and the weight of thousands of seeds (Herzog and Geisler, 1977).

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With the development of the root system by CULTAN plants their reception and use of nutrients and water improves (Sommer, 2005). Sommer (2005) states that the reception of ammonium nitrogen from the depot is regulated by the assimilation performance of the plant. The whole stem is filled with assimilates until the time of blossom, like in-process store. The stored assimilates in the top part of the stem by blossoming quickly move and are stored in the reproduction organs and assimilating leaves. Assimilates in the bottom part of the stems stay available to the roots to preserve their function. The period of storing assimilates in the cobs is thanks to the preservation of the roots function prolonged in comparison with plants supplied by nitrogen in the form of nitrates. Due to this behavior, ammonia from CULTAN application is thanks to its effect understood to be a dominant fertilizer (Sommer and Scherer, 2007).

The aim of the trial was to assess the influence of injection fertilization by CULTAN method on the yield of dry matter, the dynamics of nitrogen uptake, the content of macro elements in the above-ground biomass during in phase BBCH 89 (fully ripe) and the occurrence of diseases in relation to the fertilization variant compared with the conventional method of fertilization by nitrogen.

Material and Methods

Site, soil and treatments

The experiment with maize was conducted from the year 2010 to 2012 in the Czech Republic at sites Hněvčeves (50°18’4 6.269”N, 15°42’51.552”E), Humpolec (49°32’49.604”N, 15°21’6 .405”E) and Ivanovice na Hané (49°18’34.209”N, 17°5’18.753”E) (soil-climatic characteristic of the stations - Table 1) with maize (*Zea mays* L.) hybrid Texxud, FAO 340. The experiment consisted of 4 treatments, each with 4 trials. The area of the fertilized allotment was 45 m^2 (3 x 15 m), out of which 19.6 m^2 (1.4 x 14 m) was harvested. The experiment scheme is depicted in Table 2. The conventional method of nitrogenous nutrition by even application of fertilizer CAN on the soil surface before sowing was compared with the local injection of nitrogenous fertilizer by CULTAN method. The application of the fertilizer by CULTAN method was performed by the plant height of 20 cm (Sommer et al., 2002) by injection machine GFI 3A (Maschinen und Antriebstechnik GmgH, Germany), 3 m wide, in the distance of 10 cm from the plant line, in the depth of 5 cm. 12 application wheels form the injection applicator. Agrotechnical measures were standard technology of growing maize. During vegetation, aboveground matter in phase BBCH 14 (3 leaves unfolded, 8 plants), BBCH 20 (9 or more leaves unfolded, 5 plants), and in the phase BBCH 89 (fully ripe, 3 plants) was taken up. The samples served to determine content of dry matter, content of nitrogen and other macroelements. Agroclimatic conditions of experimental sites are stated in Tables 3-5.

Chemical analyses

The content of nitrogen in the biomass was determined by Kjeldahl method on the Vapodes 50s machine (Gerhardt

Table 2
Fertilization system of field trial

	Treatment	Before sowing	CULTAN (plant height 20 cm)
1	CAN - convectional	140 kg N.ha^{-1}	
2	CULTAN UAN		140 kg N.ha^{-1}
3	CULTAN UAS		140 kg N.ha^{-1}
4	CULTAN UAN + IN		140 kg N.ha^{-1}

CAN: Calcium Ammonium Nitrate, 27% N
UAN: Urea Ammonium Nitrate, 30% N
UAS: Urea Ammonium Sulphate, 24% N, 6% S
UAN + IN: Urea Ammonium Nitrate (30% N)+ inhibitors of nitrification

Table 1
Characteristics of experimental sites

Site	Hněvčeves	Humpolec	Ivanovice na H.
Altitude, m.n.m	265	525	225
Precipitation, mm	597	667	548
Average temperature per year, °C	8.1	6.5	9.2
Soil suborders	haplic luvisol	cambisol	chernozem
Soil type	clay loam	sandy loam	loam
pH ($CaCl_2$)	6.3	6.6	7.3
Ca, mg.kg^{-1}, Mehlich III	2 522	2 217	4 458
Mg, mg.kg^{-1}, Mehlich III	185	183	287
K, mg.kg^{-1}, Mehlich III	291	197	390
P, mg.kg^{-1}, Mehlich III	89	120	142

GmbH& Co. KG., Germany). The contents of P and S were determined by optical emission spectrometry with inductively bound plasma on ICP – OES machine (Varian, Australia). The contents of K, Ca, and Mg were diagnosed by atomic absorption spectrometry on SpectrAA machine (Varian, Australia). The occurrence of pests and diseases was assessed throughout the time of the trial along with the agrobiologic vegetation control. The following diseases were observed in the experiment: *Helmintosporium maydis, Ustilago maydis* and *Fusarium* spp.

Table 3
Agroclimatic conditions at Hněvčeves Experimental Site

	Year	Month						
		IV	V	VI	VII	VIII	IX	X
Precipitation, mm	2010	55	183	31	66	147	103	12.4
	2011	12	49	45	125	78	39	40
	2012	40	47	47	93	42	44	52
	1971-2000	28	55	61	75	67	48	41
Air Temperature, °C	2010	9.1	12.4	17.3	21.4	18.3	12.7	7.4
	2011	11.8	14.3	18.1	17.6	19.6	15.7	8.9
	2012	6.5	12.8	14.8	16.0	16.5	11.3	5.7
	1971-2000	8.6	14.0	16.5	18.5	18.4	13.8	8.8

Table 4
Agroclimatic conditions at Humpolec Experimental Site

	Year	Month						
		IV	V	VI	VII	VIII	IX	X
Precipitation, mm	2010	50	110	84	100	149	96	6
	2011	47	59	103	159	106	89	36
	2012	38	63	75	129	74	52	44
	1971-2000	42	70	78	88	85	56	40
Air Temperature, °C	2010	8.3	11.7	18.0	20.7	17.5	11.6	6.5
	2011	11.1	14.4	17.9	17.3	19.2	15.3	8.3
	2012	9.1	15.3	17.9	18.9	19.0	13.8	7.6
	1971-2000	6.2	12.0	15.1	16.8	16.4	12.0	6.8

Table 5
Agroclimatic conditions at Ivanovice na Hané Experimental Site

	Year	Month						
		IV	V	VI	VII	VIII	IX	X
Precipitation, mm	2010	45	210	90	91	127	67	8
	2011	31	58	85	71	57	26	23
	2012	38	65	75	64	61	41	34
	1971-2000	34	61	72	73	62	55	40
Air Temperature, °C	2010	9.4	13.1	18.7	21.4	18.8	13.0	6.8
	2011	11.5	14.4	18.4	18.1	19.8	16.1	8.5
	2012	9.9	15.8	18.6	20.0	19.9	15.0	8.7
	1971-2000	9.8	15.0	18.0	1.9	19.6	14.4	9.2

Statistic analyses

The evaluation of results was performed by one-factor analysis of variance ANOVA, followed by Scheffe's test in program Statistica 9.1 (StatSoft, USA), level of significance $p < 0.05$. The values in individual columns and in individual phases marked by same letters show no significant differences on the given level of significance.

Results and Discussion

Dry matter content

The proportional content of dry matter in phases BBCH 14, BBCH 20 and in the phase BBCH 89 (fylly ripe) is stated in Table 6. The dynamics of the aboveground biomass formation is dependent on the site conditions and on the weather in the given year (Troxler and Thomet, 1986). In phase BBCH 14 comparable content of dry matter was observed by all fertilized treatments. At sites Humpolec and Ivanovice na Hané, the differences in proportional content of dry matter in this phase were statistically insignificant in relation to the fertilization treatment. Even though at the beginning the maize plants fertilized by CULTAN method seem to be suffering from a lack of nitrogen compared with plants fertilized by a conventional method on the soil surface before sowing, no statistically significant difference in the content of dry matter in the aboveground biomass was observed.

In 2011 at Hněvčeves site, a statistically lower content of dry matter in the aboveground biomass by treatment CULTAN UAN in phase BBCH 14 was found, the difference was compared with a conventional treatment 10%, and by 2 other injection treatments there was a tendency to a lower content of dry matter. We can assume that lower temperatures and frosts caused it in May, which affected the reception of nutrients from the CULTAN depot. However, in phase BBCH 18 in 2011 at Hněvčeves site, there was a tendency to a higher content of dry matter by CULTAN treatments. A similar occurrence was found in 2012, when the content of dry matter was higher by 10.2 % by injection treatment CULTAN UAS + IN, which is in compliance with the findings of Flisch et al. (2013) that maize fertilized by CULTAN methods in the conditions of Switzerland achieved a higher content of dry matter than conventionally fertilized maize. The difference was statistically evident. By the same treatment was found a higher content of dry matter also at Humpolec site, statistically evident difference was 6 % in comparison with the conventional treatment. At site Ivanovice na Hané the content of dry matter in phase BBCH 18 was comparable in all experimental years, which can be caused by an intense seasonal mineralization of organic nitrogen forms, which increases the accessibility of nitrogen (Ma et al., 1999). Maize plants were taking accessible nitrogen principally from the soil and therefore the increase of dry matter is comparable regardless of the fertilization treatment. In the phase BBCH 89 there was generally a tendency to a higher content of dry matter, with the exception of 2012 in Hněvčeves, which can be explained by an overall delay of vegetation caused by late sowing. Another exception is Humpolec in 2010, where it was caused by wet weather in August and September, when CULTAN plants formed fewer assimilates, while conventional plants translocated already formed assimilates. In Hněvčeves in 2010 and Humpolec in 2010 and 2011, the statistically highest content of dry matter was observed by treatment CULTAN UAN + IN compared

Table 6
Dry matter content in aboveground maize biomass (%)

	Treatment	Hněvčeves			Humpolec			Ivanovice na H.		
		2010	2011	2012	2010	2011	2012	2010	2011	2012
BBCH 14	1	7.31^{a}	11.86^{a}	6.98^{a}	12.9^{a}	12.09^{a}	11.48^{a}	13.04^{a}	11.6^{a}	17.3^{a}
	2	7.46^{a}	10.68^{b}	7.31^{a}	13.3^{a}	12.05^{a}	11.49^{a}	13.2^{a}	11.1^{a}	15.1^{a}
	3	7.13^{a}	11.2^{ab}	6.79^{a}	12.9^{a}	11.9^{a}	11.5^{a}	13.2^{a}	11.2^{a}	16.2^{a}
	4	7.16^{a}	11.3^{ab}	7.73^{a}	13.2^{a}	12.1^{a}	10.8^{a}	13.1^{a}	12.1^{a}	16.7^{a}
BBCH 20	1	16.9^{a}	13.4^{a}	13.7^{a}	13.1^{a}	13.3^{a}	11.3^{a}	17.3^{a}	10.5^{a}	10.3^{a}
	2	16.0^{a}	13.3^{a}	13.5^{a}	13.1^{a}	13.3^{ab}	10.7^{a}	15.8^{a}	10.5^{a}	10.3^{a}
	3	16.25^{a}	14.5^{a}	13.68^{a}	12.8^{a}	13.3^{ab}	10.3^{a}	15.7^{a}	10.3^{a}	10.3^{a}
	4	16.27^{a}	15.1^{a}	15.1^{b}	12.8^{a}	14.1^{b}	10.7^{a}	16.2^{a}	10.2^{a}	10.5^{a}
BBCH 89	1	32.83^{a}	45.3^{a}	32.7^{c}	41.7^{a}	45.0^{a}	31.4^{a}	38.7^{a}	45.9^{a}	36.0^{a}
	2	32.74^{a}	45.4^{a}	30.7^{a}	39.5^{a}	45.6^{ab}	34.2^{b}	38.5^{a}	46.0^{a}	36.7^{a}
	3	34.19^{ab}	45.97^{a}	33.14^{bc}	37.02^{a}	47.5^{ab}	33.46^{b}	39.73^{a}	47.7^{a}	36.7^{a}
	4	34.62^{b}	46.7^{a}	31.26^{abc}	38.1^{a}	47.9^{b}	33.8^{b}	41.9^{a}	48.1^{a}	36.7^{a}

Values within the column marked with the same letter are not statistically different ($P< 0.05$)

with the conventionally fertilized treatment, which complies with the findings of Sommer (2003) that CULTAN plants have by 10-15 % higher content of dry matter than plants receiving nitrate nitrogen. The cells of CULTAN plants are often smaller with stronger cell walls and the osmotic pressure in these cells is smaller, because these cells miss the osmoregulatory effect of nitrate with its appending cations, especially calcium. A similar tendency was found in the Czech Republic conditions by Peklová et al. (2011) and Sedlář et al. (2011) by *Brassica napus* L. and *Hordeum vulgare* L. fertilized by injection through CULTAN method. Sommer (2005) points out that a higher content of dry matter by plants fertilized by CULTAN method is a prerequisite for smaller occurrence of diseases. During the three-year trial, however, we did not find any statistically significant effect of the CULTAN method on the occurrence of diseases by maize plants. The occurrence of diseases was dependent on the year and the site and was moderate at all sites in all years (Kubešová et al*.*, 2012).

Dynamics of nitrogen uptake

The dynamics of nitrogen uptake are stated in Table 7. The uptake of nitrogen in phase BB14 at site Hněvčeves was comparable among all treatments of fertilization. Only in 2010, when May and June were under average on temperature, there was a statistically bigger take-up of nitrogen by the injection treatment with sulphur, which complies with the view of De Kok et al. (2003) that sulphur supports reception of nitrogen. Also in the following two years, the biggest uptake of nitrogen was observed by the injection CULTAN treatment with sulphur. In phase BBCH 20 treatment, CULTAN UAS reached bigger uptakes of nitrogen in 2011 and 2012. In this phase, statistically smaller uptake of nitrogen was observed by the injection treatment with nitrification inhibitor, which can be explained by lower temperatures of the soil, which might have led to an increase in stability of nitrogen in the depot and consequently lower its acceptability. In 2011 and 2012 in phase BBCH 20 there was a bigger uptake of nitrogen by treatments CULTAN UAS and CULTAN UAN+IN, which is possible to explain by the fact that the nitrogen from CULTAN depot was more acceptable, also in a period under average on precipitation, than the nitrogen from areally applied CAN on the soil surface, when its acceptability is influenced by the amount of precipitation (Peterson, 2001). In 2010 in phase BBCH 14 both at sites Humpolec and Ivanovice, the nitrogen uptake was smaller by CULTAN treatments, which can be explained by smaller accessibility of nitrogen from the CULTAN depot due to lower temperatures of the soil. At Ivanovice site, there was even a statistically evident difference by treatments with an inhibitor that year. However, in the following year, when the temperatures seemed on average, the treatment with an inhibitor reached a bigger uptake compared with the conventional treatment. Only in phase BBCH 20 at Humpolec site, which is located in a colder area, there were bigger uptakes of nitrogen by the injection treatment with sulphur in 2010 and 2011, which supports the findings of Salvaggioti et al. (2009) that by adding sulphur into a nitrogenous fertilizer its effectiveness increases. Nevertheless, all injection treatments achieved nitrogen uptakes comparable with the conventional treatment. In phase BBCH 20 at Ivanovice site, the uptake of nitrogen was comparable by all treatments.

In the phase BBCH 89 Hněvčeves site, all treatments reached comparable nitrogen uptakes. In 2011 the injection

Table 7
Dynamics of nitrogen uptake (kg N/ha)

	Treatment	Hněvčeves			Humpolec			Ivanovice na H.		
		2010	2011	2012	2010	2011	2012	2010	2011	2012
BBCH 14	1	36^{ab}	47^{a}	49^{a}	29^{a}	33^{a}	16^{a}	183^{a}	107^{a}	125^{a}
	2	37^{ab}	40^{b}	50^{a}	21^{b}	35^{a}	16^{a}	165^{ab}	104^{ab}	111^{a}
	3	41^{b}	46^{a}	50^{a}	22^{b}	34^{a}	15^{a}	176^{ab}	112^{ab}	121^{a}
	4	33^{a}	41^{ab}	48^{a}	24^{ab}	30^{a}	14^{a}	167^{b}	124,^{b}	131^{a}
BBCH 20	1	101^{a}	251^{a}	297^{a}	107^{a}	42^{ab}	33^{a}	272^{a}	264^{a}	171^{a}
	2	86b	218^{b}	308^{ab}	83^{b}	47^{ab}	33^{a}	278^{a}	271^{a}	188^{a}
	3	92^{ab}	281^{c}	308^{ab}	106^{a}	49^{a}	32^{a}	269^{a}	251^{a}	168^{a}
	4	89^{ab}	308^{c}	333^{b}	92^{ab}	38^{b}	30^{a}	272^{a}	254^{a}	179^{a}
BBCH 89	1	327^{a}	364^{a}	334^{a}	163^{a}	159^{a}	208^{a}	310^{a}	234^{a}	200^{a}
	2	314^{a}	427^{b}	296^{b}	138^{b}	154^{a}	198^{a}	332^{b}	248^{ab}	219^{a}
	3	327^{a}	342^{a}	362^{a}	169^{a}	149^{a}	213^{a}	304^{a}	275^{b}	226^{a}
	4	322^{a}	359^{a}	353^{a}	161^{a}	143^{a}	196^{a}	302^{a}	243^{ab}	219^{a}

Values within the column marked with the same letter are not statistically different ($P< 0.05$)

treatment CULTAN UAN+IN achieved a statistically bigger uptake than the conventional treatment, which can be explained by placing the fertilizer in an accessible and stable form for a longer vegetation period (Sommer, 2005). In 2012, the sowing at this site was delayed and it reflected on the nitrogen uptake in relation to the fertilization treatment. Treatment CULTAN UAS in 2012 at Hněvčeves and in 2011 at Ivanovice, reached statistically significantly bigger nitrogen uptakes by the whole plant in the phase BBCH 89, which supports the view of Vaněk et al. (2007) that ammonium sulphate is the most suitable fertilizer for maize. At all sites in all trial years, a bigger amount of nitrogen was taken up than

Table 8
The content of micro elements in the whole plants in the phase BBCH 89 (%)

Site	Year	Treatment	P	S	Ca	Mg	K
Hněvčeves	2010	1	0.36[a]	0.14[a]	0.38[a]	0.11[a]	1.16[a]
		2	0.36[a]	0.14[a]	0.39[a]	0.12[a]	1.20[a]
		3	0.39[a]	0.14[a]	0.38[a]	0.12[a]	1.28[a]
		4	0.36[a]	0.14[a]	0.38[a]	0.12[a]	1.28[a]
	2011	1	0.21[a]	0.14[a]	0.44[a]	0.08[a]	1.32[a]
		2	0.28[a]	0.13[a]	0.46[a]	0.09[a]	1.32[a]
		3	0.21[a]	0.10[a]	0.40[a]	0.06[a]	1.30[a]
		4	0.26[a]	0.10[a]	0.41[a]	0.08[a]	1.29[a]
	2012	1	0.31[a]	0.13[a]	0.43[a]	0.11[a]	1.24[a]
		2	0.31[a]	0.14[a]	0.48[a]	0.10[a]	1.28[a]
		3	0.29[a]	0.10[a]	0.45[a]	0.11[a]	1.27[a]
		4	0.30[a]	0.12[a]	0.44[a]	0.10[a]	1.30[a]
Humpolec	2010	1	0.14[a]	0.09[a]	0.75[a]	0.06[a]	2.09[a]
		2	0.16[a]	0.10[a]	0.91[a]	0.05[a]	2.67[b]
		3	0.15[a]	0.10[a]	0.80[a]	0.05[a]	2.46[ab]
		4	0.17[a]	0.10[a]	0.94[a]	0.05[a]	2.65[b]
	2011	1	0.13[a]	0.10[a]	0.65[a]	0.11[a]	2.23[a]
		2	0.13[a]	0.13[a]	0.72[a]	0.10[a]	2.48[a]
		3	0.15[a]	0.11[a]	0.68[a]	0.12[a]	2.50[a]
		4	0.14[a]	0.11[a]	0.69[a]	0.12[a]	2.39[a]
	2012	1	0.16[a]	0.12[a]	0.88[a]	0.10[a]	2.00[a]
		2	0.15[a]	0.13[a]	0.85[a]	0.10[a]	1.91[a]
		3	0.16[a]	0.15[a]	0.87[a]	0.11[a]	1.95[a]
		4	0.18[a]	0.13[a]	0.89[a]	0.10[a]	1.71[a]
Ivanovice na H.	2010	1	0.25[a]	0.15[a]	1.31[a]	0.05[a]	1.42[a]
		2	0.23[a]	0.15[a]	1.20[a]	0.04[a]	1.38[a]
		3	0.23[a]	0.14[a]	1.31[a]	0.05[a]	1.42[a]
		4	0.23[a]	0.11[a]	1.30[a]	0.05[a]	1.47[a]
	2011	1	0.17[a]	0.13[a]	0.62[a]	0.12[a]	1.2[a]
		2	0.19[a]	0.20[b]	1.3[b]	0.11[a]	2.1b
		3	0.18[a]	0.17[ab]	0.87[ab]	0.12[a]	1.6[ab]
		4	0.18[a]	0.15[ab]	0.71[ab]	0.12[a]	1.46[ab]
	2012	1	0.21[a]	0.14[a]	0.99[a]	0.11[a]	1.33[a]
		2	0.20[a]	0.14[a]	1.00[a]	0.11[a]	1.28[a]
		3	0.19[a]	0.15[a]	1.03[a]	0.12[a]	1.39[a]
		4	0.20[a]	0.14[a]	0.98[a]	0.11[a]	1.41[a]

Values within the column marked with the same letter are not statistically different (P< 0.05) had been applied by all treatments. It is possible to assume, based on the observed nitrogen uptake dynamics that the stability of nitrogen in a CULTAN depot decreases only after phase BBCH 20 when in biologically active soils nitrification increases due to higher temperatures. We may assume that in the following phases of growth, plants fertilized by CULTAN method receive nitrate nitrogen created by nitrification of ammonium nitrogen stored in the depot. Flisch et al. (2013) made a similar conclusion.

Marcoelements content in maize plant

The proportional content of phosphor, sulphur, calcium, magnesium and potassium in the aboveground biomass of maize in the phase BBCH 89 (fully ripe) is stated in Table 8. The year and the site mostly influence the content.

Maize in general requests phosphor (Nagy, 2006). The content of phosphor in the aboveground biomass was not statistically different among the treatments in the phase

BBCH 89. Kirkby (1968) states that by plants receiving nutrients from an ammonium form of nitrogen the reception of phosphor increases. If the roots receive NH_4^+, there is a strong excretion of protons. Because of a change of balance in the roots pH of the rhizosphere decreases and the phosphor, gets mobilized (Trenkel, 1997). Our results do not comply with the results of Sigung et al. (2002) who observed a bigger reception of phosphor by maize by the application of ammonium sulphate.

The content of sulphur in the completely maize plants in the phase BBCH 89 was smaller. Vaněk et al. (2007) states as an insufficiency of sulphur the limit of 20 (10) mg/kg of dry matter. The greatest lack of sulphur is at site Humpolec, which complies with the results of Kulhánek et al. (2011). The contents of sulphur showed no statistical difference among the treatments of fertilization, only in 2012 at Ivanovice site, treatment CULTAN UAN achieved a bigger content of sulphur. These results do not comply with the statement that plants receiving nutrients from ammonium form of nitrogen have a better reception of sulphur (Herada et al., 1968). However, the reception of ammonium nitrogen by a plant, provided it is applied evenly into the soil, is accompanied by a smaller reception of non-organic cations Ca, Mg, K (Kirkby, 1968; Gerendas et al., 1997). No statistically evident difference in the content of Mg was found during the trial. Sommer (2005) explains this fact by only a small integration of the root system into such antagonism (max. 5.0% of the whole root system).

Sommer and Scherer (2007) state that the reception of nutrients and water on the contrary increases, as plants fertilized by CULTAN method have a bulkier root system caused by putting off the time of fertilizer application and by a bigger production of cytokinins. This may also explain a statistically bigger content of calcium and potassium in the whole plants in the phase BBCH 89 at site Ivanovice in 2011 by treatment CULTAN UAN, when the summer months had lower than average precipitation. Otherwise, the contents of calcium were comparable between the conventional and the injection treatments.

Engels and Marschner (1993) found a bigger content of potassium by maize plants receiving nutrients from ammonium form of nitrogen. Our results cannot completely confirm this finding, but we may assume that the effect of CULTAN method on the development of the root system is much bigger than the effect of the nitrogen form itself.

Conclusion

Based on the results of the three-year trial, it is possible to assume that the influence of the fertilization treatment on the observed parameters was smaller than the influence of agro-climatic conditions and the site. Plants fertilized by CULTAN method achieved the same or slightly bigger content of dry matter. By injection treatments, there was a positive effect of adding sulphur into the fertilizer on the nitrogen uptake in all observed phases. The contents of phosphor, sulphur and magnesium in the above-ground biomass of the whole plants in the phase BBCH 89(fully ripe) proved no statistical difference in relation to the fertilization treatment.

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