RESEARCH REGARDING THE INFLUENCE OF NPK AND NP FERTILIZATION ON CADMIUM CONCENTRATION FROM WHEAT AND MAIZE GRAINS, IN A LONG TERM TRIAL FROM ORADEA

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Abstract

The paper is based on research carried out at the Agricultural Research and Development Station Oradea, in long term trial with NPK (placement year 1974) and with NP (placement year 1974). The research carried out during 2010-2012, shows that in all variants that were chemical fertilized, the concentration of cadmium from wheat grains and maize grains was far above the admitted limits. The concentration of cadmium concentration from wheat grains and maize grains increased altogether with the fertilizers' doses. Regarding the version with NP doses, cadmium concentration from wheat and maize grains, was higher than cadmium concentration from wheat and maize grains, determined at NPK fertilized version. There is a direct interrelation between fertilizer doses of NPK and NP and cadmium concentration from wheat and maize grains; the best quantifications of this interrelation was carried out by polynomial function. During 2010, while the vegetation period of those two crops were registered precipitations over the multiannual average value (1931-2009) of this climatic parameter, cadmium concentration from wheat and maize grains was lower than during 2011 and 2012, when precipitations were registered under the multiannual average value.

Keywords: long term trial, chemical fertilizers, winter wheat, maize, grains, cadmium

INTRODUCTION

The scientific studies show that the contamination with heavy metals of the environment data since the time of the original magma of the Earth began to solidify (Ross S.M., 1994). Excessive concentrations of heavy metals in the soil, without human impact, are the result of natural nitrogen mineralisation (Turner, 1994).

Sometimes, agricultural activities, including vegetal and animal production and utilization of natural water sources are incorrectly and unconsciously performed, although they can be equally constructive and destructive.

Cadmium (Cd) is accumulated in soil via natural processes and anthropogenic activities, such as atmosphere deposition, industrial activities, sewage sludge disposal and fertilizer application (Adams et al. 2004; Fan et al. 2009). It can accumulate in crops, such as winter wheat, and its accumulation depends on crop species, soil factors, and agricultural practices like fertilizer inputs (Li X et al, 2011).

Application of chemical fertilizers with nitrogen, phosphorus and potassium in moderate doses does not lead to significant increases of heavy metals concentrations in grain (Orosz et al., 2009).

Soil type from Oradea, Romania, is preluvosoil and is also a medium that provides the main nutritive elements, with a weak acid reaction in the ploughing horizon (Ciobanu, 2007, Vuşcan et al., 2010). Many researchers on preluvosoil (Samuel et al., 2008, Domuța,

2009) have shown the negative effect of long-term application of nitrogen, as ammonium nitrate, on soil reaction.

The factors which have a negative influence on heavy metals concentration are high level soil content in the H^+ and Al^{3+}, Fe^{2+} and Mn^{2+} and low level soil content in main nutrients, low activity of microorganisms (Samuel, 2009), and stagnation of water because of unsatisfactory infiltration (Şandor et al., 2008, Brejea, 2010).

The purpose of this study is to assess the degree of contamination with Cd in wheat and maize grains in long term field experiments with nitrogen, phosphorus and potassium fertilizers.

MATERIAL AND METHOD

The research data was obtained at the Agricultural Research and Development Station Oradea, using a unique design in all research networks of Fundulea National Agricultural Research and Development Institute.

The investigation has been carried out beginning with the autumn of 1974 in Oradea, in a flat plain area on the third terrace of Crisul Repede River.

The crop rotation pea – winter wheat – maize – sunflower was used in the field experiment with potassium fertilizers.

The factors under study were the potassium and NP rates applied:

a. potassium rate : K_0, K_{40}, K_{80}, K_{120}

b. NP rates: N_0P_0; $N_{80}P_{40}$; $N_{80}P_{80}$; $N_{160}P_{80}$. (N was applied like ammonium nitrate, in spring, P was applied like superphosphate and K like KCl in autumn).

In experiment with phosphorus and nitrogen fertilizers, the experimental factors were:

a. phosphorus rates: P_0, P_{40}, P_{80}, P_{120}, P_{160}

b. nitrogen rates: N_0, N_{40}, N_{80}, N_{120}, N_{160}

The crop rotation was: bean – winter wheat – sunflower – maize – wheat.

The elements of technologies utilized complied with the most recent recommendations in this area.

Grain concentration of heavy metals was determined using the mineralization with sulphuric and perchloric acid mixture method. The results were determined by using the atomic absorption spectrophotometer.

Aspect from the research field

RESULTS AND DISCUSSION

The climate elements during the examined period

In Oradea, the multiannual rainfall average registered during the period of wheat vegetation (October - June) is 438 mm; back in 2010, this value increased with 44.4%, while in 2011 and 2012 the rainfalls registered decreased with 7.3% in 2011 and 26.8% in 2012 in comparison with the multinational value. During those three years, the mean temperature of October – June period (8.5^{o}C in 2010, 8.1^{o}C in 2011 and 7.5^{o}C in 2012) was

higher than the average monthly value (7.2°C). The air humidity had lower value than the multiannual average (8.1%), even in the rainiest year (2010) (Table 1).

Regarding the vegetation period of maize (April - September), the average monthly value of rainfalls is 367.0 mm; only in 2010 there was registered one positive exception (36.1%) to the multiannual average, in 2011 and 2011 the registered rainfall representing 75.2% of the multiannual average value; in 2012 the registered rainfalls (298.5 mm) represented 81.4% of the multiannual average value. In the three years the mean temperature of the air for April – September period had higher values than the multiannual value, the year 2012 increasing up to 27.8°C (a difference of 15.8%).

In 2010, the air humidity had a 5.6% higher value than the multiannual average value; in 2011 the values were 11.9% lower than the multiannual average value, and in 2012 the values were 12.5% lower than the multiannual average value (Table 2).

Table 1

The climate elements during vegetation period of wheat, Oradea 2010 – 2012
(according to Meteorological Station Oradea)

Agricultural year	Month									Sum/ Average
	X	XI	XII	I	II	III	IV	V	VI	
Rainfall - mm										
2010	91.5	86.0	55.6	63.1	48.8	24.3	61.2	118.9	82.8	632.3
2011	52.5	76.7	91.2	25.5	19.4	28.7	19.0	56.5	35.2	404.7
2012	15.6	0.10	54.0	23.2	23.0	4.6	40.7	65.0	94.1	320.3
Multiannual average	39.7	48.7	50.4	34.3	38.7	34.6	46.1	61.1	84.9	438.0
Air temperature - °C										
2010	11.3	7.7	3.0	-1.3	2.4	6.1	11.5	16.2	19.8	8.5
2011	8.2	9.2	0.5	-0.1	-1.2	6.0	12.4	16.8	21.2	8.1
2012	9.8	1.9	3.1	0.6	-5.7	6.5	12.5	17.2	21.8	7.5
Multiannual average	10.6	5.3	0.6	-2.0	0.3	5.0	10.5	15.8	19.1	7.2
Air humidity - °C										
2010	80	85	81	86	87	74	77	76	73	80
2011	76	78	90	88	83	73	60	64	62	75
2012	72	80	89	86	81	57	66	69	68	74
Multiannual average	79	84	88	85	86	86	72	72	73	81

Table 2

The climate elements during vegetation period of maize, Oradea 2010 – 2012
(according to Meteorological Station Oradea)

Agricultural year	Month						Average amount
	IV	V	VI	VII	VIII	IX	
Rainfall - mm							
2010	61.2	118.9	82.8	81.6	82.3	72.9	499.7
2011	19.0	56.5	35.2	125.3	8.9	30.8	275.7
2012	40.7	65.0	94.1	70.8	6.5	21.4	298.5
Multiannual average	46.1	61.1	84.9	70.9	58.7	45.3	367.0
Air temperature - °C							
2010	11.5	16.2	19.8	22.4	21.6	15.2	17.8
2011	12.4	16.8	21.2	21.8	22.6	19.3	19.0
2012	12.5	17.2	21.8	24.6	23.4	19.5	19.8
Multiannual average	10.5	15.8	19.1	20.8	20.0	16.2	17.1
Air humidity - °C							
2010	77	76	73	75	77	78	76
2011	60	64	62	69	64	64	64
2012	69	69	68	62	52	59	63
Multiannual average	72	72	73	69	71	75	72

Cadmium concentration from wheat grains depending on doses and concentration of NPK

In all those three years of study, the lowest concentration of cadmium was registered at control version, without chemical fertilizers ($N_0P_0K_0$). The version fertilized with $N_{40}P_{40}K_{40}$, the cadmium concentration increased (11.2% in 2010, 13.5% in 2011 and 20.3% in 2012), but the differences with respect to the control version are statistically insignificant. For the version fertilized with $N_{80}P_{80}K_{80,}$ the differences registered are higher than those from the previous version; the version fertilized with $N_{160}P_{80}K_{120}$ registered the highest values with respect to the control version; in both situations, the differences with regard to control version, registered in all three years that were studied are statistically significant (Table 3).

Table 3

The influence of doses and combinations of NPK fertilizers on the cadmium concentration in wheat grains, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
2010					
$N_0P_0K_0$	0.107	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.119	111.2	0.012	11.2	-
$N_{80}P_{80}K_{80}$	0.133	124.3	0.026	24.3	*
$N_{160}P_{80}K_{120}$	0.143	133.6	0.036	33.6	*
		LSD 5%	0.021		
		LSD 1%	0.039		
		LSD 0,1%	0.082		
2011					
$N_0P_0K_0$	0.111	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.126	113.5	0.015	13.5	-
$N_{80}P_{80}K_{80}$	0.142	127.9	0.031	27.9	-
$N_{160}P_{80}K_{120}$	0.151	136.0	0.040	36.0	*
		LSD 5%	0.018		
		LSD 1%	0.041		
		LSD 0,1%	0.078		
2012					
$N_0P_0K_0$	0.113	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.136	120.3	0.023	20.3	-
$N_{80}P_{80}K_{80}$	0.151	133.6	0.038	33.6	*
$N_{160}P_{80}K_{120}$	0.156	138.1	0.043	38.1	*
		LSD 5%	0.026		
		LSD 1%	0.045		
		LSD 0,1%	0.090		

In all those three years of study, for the control version ($N_0P_0K_0$), the average of cadmium concentration from wheat grains was 0.110 mg/kg. The other versions registered higher concentration, but the difference registered in $N_{80}P_{40}K_{40}$ (15.4%) is statistically insignificant, and the differences determined in the other two versions (29.1% and 36.4%) are only statistically significant (Table 4).

Table 4

The influence of doses and combinations of NPK fertilizers on the cadmium concentration in wheat grains, average data, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
$N_0P_0K_0$	0.110	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.127	115.4	0.017	15.4	-
$N_{80}P_{80}K_{80}$	0.142	129.1	0.032	29.1	*
$N_{160}P_{80}K_{120}$	0.150	136.4	0.040	36.4	*
		LSD 5%	0.022		
		LSD 1%	0.042		
		LSD 0.1%	0.084		

Mathematical analyses of data regarding cadmium concentration in wheat grains from all four versions that were studied, shows that from five functions that were tested (exponential, linear, logarithmic, polynomial, power), the polynomial function is the best statistically provided (Fig. 1).

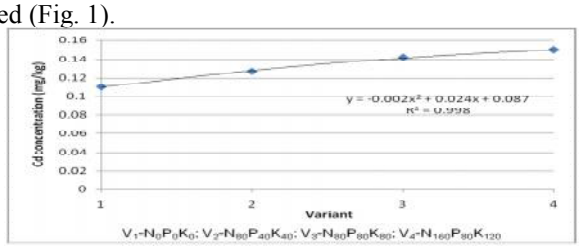

Fig.1. Correlation between NPK fertilizers doses and cadmium concentration from wheat grains, Oradea 2010 – 2012

Cadmium concentration from wheat grains depending on doses and concentration of NP

In the control version (N_0P_0) there were registered the lowest values of cadmium concentration in wheat grains: 0.110 mg/kg in 2010, 0.112 mg/kg in 2011 and 0.114 mg/kg in 2012. The version fertilized with $N_{40}P_{40}$ registered higher concentrations, but the differences with respect to the control version, 16.4% in 2010, 17.0% in 2011 and 17.5% in 2012. The version fertilized with $N_{80}P_{80}$ registered higher differences in comparison with the control version, statistically significant in 2010 (29.1%) and 2012 (30.7%) and statistically insignificant in 2011 (0.022 mg/kg, 28.6%). The biggest differences with respect to the unfertilized control version (60.0% in 2010, 67.9% in 2011 and 68.4% in 2012) were registered for the version fertilized with $N_{160}P_{160}$. In these three years, those differences were statistically significant (Table 5).

Table 5

The influence of doses and combinations of NP fertilizers on the cadmium concentration in wheat grains, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
2010					
N_0P_0	0.110	100	-	-	Control
$N_{40}P_{40}$	0.128	116.4	0.018	16.4	-
$N_{80}P_{80}$	0.142	129.1	0.032	29.1	*
$N_{160}P_{160}$	0.176	160.0	0.066	60.0	**
		LSD 5%	0.031		
		LSD 1%	0.069		
		LSD 0.1%	0.099		
2011					
N_0P_0	0.112	100	-	-	Control
$N_{40}P_{40}$	0.131	117.0	0.019	17.0	-
$N_{80}P_{80}$	0.144	128.6	0.022	28.6	-
$N_{160}P_{160}$	0.188	167.9	0.072	67.9	**
		LSD 5%	0.033		
		LSD 1%	0.070		
		LSD 0.1%	0.098		
2012					
N_0P_0	0.114	100	-	-	Control
$N_{40}P_{40}$	0.134	117.5	0.020	17.5	-
$N_{80}P_{80}$	0.149	130.7	0.035	30.7	*
$N_{160}P_{160}$	0.192	168.4	0.078	68.4	**
		LSD 5%	0.033		
		LSD 1%	0.068		
		LSD 0.1%	0.098		

During 2010-2012, the unfertilized control version registered on average a 0.112 mg/kg cadmium concentration value in wheat grains. The fertilized version with $N_{40}P_{40}$ had a higher cadmium concentration, but the difference (0.019 mg/kg, 16.9%) is statistically insignificant. The difference registered in fertilized version with $N_{80}P_{80}$ (0.033 mg/kg, 29.4%) is statistically significant; for the version fertilized with $N_{160}P_{160}$, the biggest difference (0.073 mg/kg, 65.2%) was registered and it is statistically significant (Table 6).

Table 6

The influence of doses and combinations of NP fertilizers on the cadmium concentration in wheat grains, average data, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
N_0P_0	0.112	100	-	-	Control
$N_{40}P_{40}$	0.131	116.9	0.019	16.9	-
$N_{80}P_{80}$	0.145	129.4	0.033	29.4	*
$N_{160}P_{160}$	0.185	165.2	0.073	65.2	**
LSD 5%			0.032		
LSD 1%			0.069		
LSD 0.1%			0.099		

Mathematical analyses of the results obtained in those three years of research show that the polynomial function quantifies the best the link between the doses of NP fertilizers and the concentration of cadmium in wheat grains. (Fig.2)

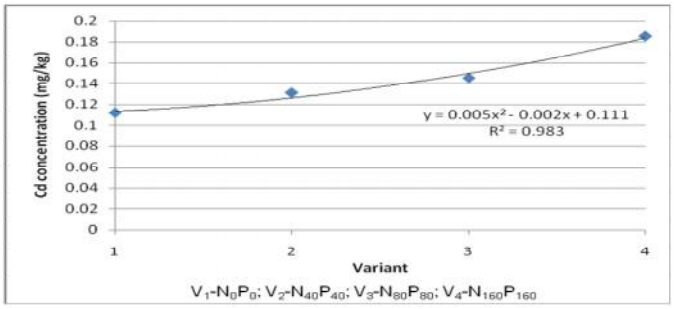

Figure 2. Correlation between NP fertilizers doses and cadmium concentration from wheat grains, Oradea 2010 – 2012

Cadmium concentration from maize grains depending on doses and concentration of NPK

The performed determinations highlighted a lower cadmium concentration in maize grains comparing with cadmium concentration in wheat grains.

During all three years of study, in the version without chemical fertilizers there was determined the lowest cadmium concentration: 0.027 mg/kg in 2010, 0.035 mg/kg in 2011 and 0.040 mg/kg in 2012. The version fertilized with $N_{80}P_{40}K_{40}$ cadmium concentration has been high comparing to the unfertilized control, but the differences are not statistically provided. The version fertilized with $N_{80}P_{80}K_{80}$ registered a higher cadmium concentration and the differences registered in these three years are higher than those registered in the previous version and they are statistically significant. The highest differences were registered in $N_{160}P_{80}K_{120}$ fertilized version, but the differences are still statistically significant. (Table 7)

Table 7

The influence of doses and combinations of NPK fertilizers on the cadmium concentration in maize grains, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
2010					
$N_0P_0K_0$	0.027	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.030	111.1	0.003	11.1	-
$N_{80}P_{80}K_{80}$	0.039	144.4	0.012	44.4	*
$N_{160}P_{80}K_{120}$	0.041	151.9	0.014	51.9	*
		LSD 5%	0.009		
		LSD 1%	0.015		
		LSD 0.1%	0.018		
2011					
$N_0P_0K_0$	0.035	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.040	114.3	0.005	14.3	-
$N_{80}P_{80}K_{80}$	0.051	145.7	0.016	45.7	*
$N_{160}P_{80}K_{120}$	0.053	151.4	0.018	51.4	*
		LSD 5%	0.010		
		LSD 1%	0.017		
		LSD 0.1%	0.025		
2012					
$N_0P_0K_0$	0.040	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.051	127.5	0.011	27.5	-
$N_{80}P_{80}K_{80}$	0.057	142.5	0.017	42.5	*
$N_{160}P_{80}K_{120}$	0.061	152.5	0.021	52.5	*
		LSD 5%	0.012		
		LSD 1%	0.023		
		LSD 0.1%	0.036		

During 2010-2012, the concentration of cadmium concentration from maize grains in the unfertilized version was 0.034 mg/kg. The versions fertilized with $N_{80}P_{40}K_{40}$ and $N_{80}P_{80}K_{80}$ registered higher cadmium concentrations in maize grains, but the differences are not statistically significant. The difference registered in $N_{160}P_{80}K_{120}$ (0,018mg/kg) fertilized version is statistically significant (Table 8).

Table 8

The influence of doses and combinations of NPK fertilizers on the cadmium concentration in maize grains, average data, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
$N_0P_0K_0$	0.034	100	-	-	Control
$N_{80}P_{40}K_{40}$	0.040	117.6	0.006	17.6	-
$N_{80}P_{80}K_{80}$	0.049	144.1	0.009	44.1	-
$N_{160}P_{80}K_{120}$	0.052	152.9	0.018	52.9	*
		LSD 5%	0.011		
		LSD 1%	0.019		
		LSD 0.1%	0.027		

The interrelation between fertilizer doses and cadmium concentration from maize grains is the best quantified by the polynomial function. (Fig.3)

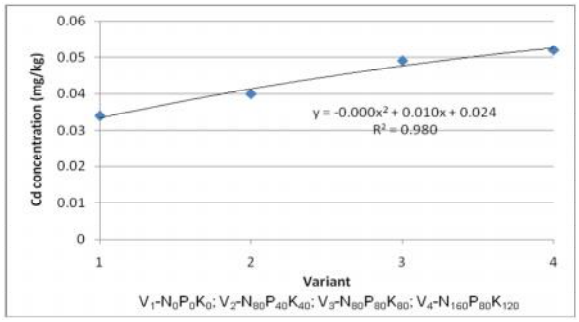

Fig. 3. Correlation between NPK fertilizers doses and cadmium concentration from maize grains, Oradea 2010 – 2012

Cadmium concentration from maize grains depending on dosages and concentration of NP

Cadmium concentration from maize grains was also lower than cadmium concentration from wheat grains, in case of the experience with NP doses and combinations.

The lowest values of cadmium concentrations were registered in the unfertilized version. During all the three years of study, cadmium concentration from maize grains was higher in the fertilized version with $N_{40}P_{40}$ comparatively with the fertilized version with N_0P_0 but the differences are not statistically significant; the version fertilized with $N_{80}P_{80}$ registered statistically significant differences, and the fertilized version with $N_{160}P_{160}$ registered the highest values of cadmium concentration, the differences being statistically significant (Table 9).

Table 9

The influence of doses and combinations of NP fertilizers on the cadmium concentration in maize grains, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
2010					
N_0P_0	0.032	100	-	-	Control
$N_{40}P_{40}$	0.039	121.9	0.007	21.9	-
$N_{80}P_{80}$	0.046	143.8	0.014	43.8	*
$N_{160}P_{160}$	0.061	190.6	0.029	90.6	**
		LSD 5%	0.008		
		LSD 1%	0.017		
		LSD 0.1%	0.032		
2011					
N_0P_0	0.035	100	-	-	Control
$N_{40}P_{40}$	0.044	125.7	0.009	25.7	-
$N_{80}P_{80}$	0.052	148.6	0.017	48.6	*
$N_{160}P_{160}$	0.069	197.1	0.034	97.1	**
		LSD 5%	0.010		
		LSD 1%	0.016		
		LSD 0.1%	0.038		
2012					
N_0P_0	0.039	100	-	-	Control
$N_{40}P_{40}$	0.049	125.6	0.010	25.6	-
$N_{80}P_{80}$	0.061	156.4	0.022	56.4	*
$N_{160}P_{160}$	0.077	197.4	0.038	97.4	**
		LSD 5%	0.014		
		LSD 1%	0.019		
		LSD 0.1%	0.032		

During 2010-2012, in the case of N_0P_0 version, the average of cadmium concentration from maize grains was 0.036 mg/kg. The version fertilized with $N_{40}P_{40}$ registered 0.044 mg/kg cadmium concentration, but the differences with the respect to the control version are not statistically significant; the version fertilized with $N_{80}P_{80}$ registered 0.053mg/kg cadmium concentration, the difference of 0.017 mg/kg being statistically significant. The highest cadmium concentration from corn kernels was registered in the fertilized version with $N_{160}P_{160,}$ 0.069 mg/kg; the difference with respect to the control version was statistically significant (Table 10).

Table 10

The influence of doses and combinations of NP fertilizers on the cadmium concentration in maize grains, average data, Oradea 2010-2012

Variant	Cd concentration		Difference		Statistical significance
	mg/kg	%	mg/kg	%	
N_0P_0	0.036	100	-	-	Control
$N_{40}P_{40}$	0.044	122.2	0.008	22.2	-
$N_{80}P_{80}$	0.053	147.2	0.017	47.2	*
$N_{160}P_{160}$	0.069	191.6	0.032	91.6	**
		LSD 5%	0.011		
		LSD 1%	0.018		
		LSD 0.1%	0.034		

The interrelation between fertilizer dozes with NP and cadmium concentration from corn kernels was the best quantified by polynomial function, $y = 0.002x^2 + 0.000x + 0.033$, $R^2 = 0.997$ (Fig. 4).

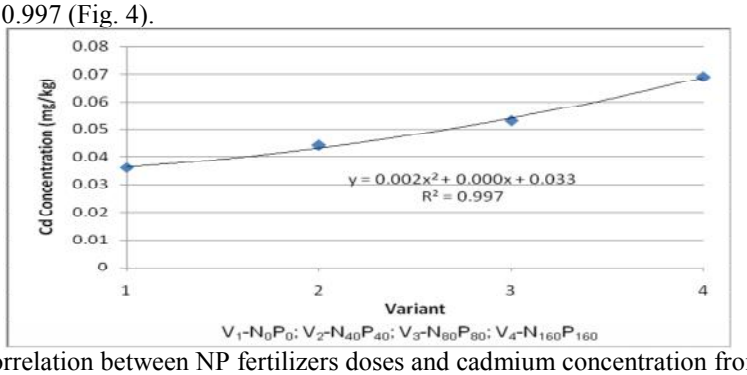

Fig. 4. Correlation between NP fertilizers doses and cadmium concentration from maize grains, Oradea 2010 – 2012

CONCLUSIONS

The research performed during 2010-2012 in long term trial with NPK and NP, regarding the influence of chemical fertilizers on cadmium concentration from wheat and maize grains, led to the next conclusions:

- Cadmium concentration from wheat and maize grains increased altogether with the fertilizers dozes.
- Regarding the version with NP doses, cadmium concentration from wheat and maize grains, was higher than cadmium concentration from wheat and maize grains, determined in NPK fertilized version.
- There is a direct interrelation between fertilizers doses of NPK and NP and cadmium concentration from wheat and maize grains; the best quantifications of this interrelation were carried out by polynomial function.

- During 2010, while the vegetation period of those two crops, there were registered precipitations over the multiannual average value (1931-2009) of this climatic parameter, cadmium concentration from wheat and maize grains was lower than those recorded during 2011 and 2012, when precipitations under the multiannual average value were registered.
- In all chemical fertilized versions, cadmium concentration from wheat and maize grains were far below the permissible limits.

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