CORRELATIONS BETWEEN THE YIELD DIFFERENCES OF SPRING WHEAT, OBTAINED ON A POLLUTED HAPLIC LUVISOIL WITH CRUDE OIL, DEPENDING ON WEATHER CONDITIONSAND FERTILIZATION SYSTEMS ON THE MITIGATION PERIOD

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Abstract

Among the different technologies used today to improve cultivated soils polluted with crude oil, the bioremediation of organic pollutants in the field, it is most commonly used, especially for the lower concentrations of pollutants because it is a method environmentally friendly and due to their reduced costs.

Research on improving the polluted with oil residue soils were held on a haplic luvisoil, planted with spring wheat, using for the stimulation of crude oil biodegradation, organic fertilization (manure) and mineral fertilization (NPK) systems.

The average values of the yield differences between the variants unpolluted (a_0) and polluted by 3% crude oil (a_1) varies inversely with the quantity of manure and complex fertilizers applied, ranging between 1.86 q/ha, on the variants without fertilization and -0.03 q/ha for the maximum doses of fertilizers applied.

The bifactorial spatial correlations (3D) between yield differences (a_0-a_1) made of spring wheat (q/ha) and climatic characteristics of the vegetation period X_1 (rainfall, mm; average temperatures, °C; the de Martonne aridity index, mm/°C) and the fertilization systems applied X_2 (manure, complex fertilizers, NPK and organic and mineral fertilization respectively), without the interaction between factor, are very significant statistically.

The biggest yield differences, betweenthe fertilization systems analyzed were obtained for the values of de Martonne aridity index between 25 and 35, values which characterize the vegetation periods in question as being from medium to very rainy, while the smallest yield differences for de Martonne aridity index values of 16.13, that indicate an excessively dry growing season.

Key words: soil pollution, crude oil, climatic indices, fertilization system, correlations,biodegradation

INTRODUCTION

Environmental pollution, marine waters and lands, by oil residues represents an environmentally potential disaster, being strongly contaminated aquatic and terrestrial ecosystems, inclusive their flora and fauna.

In Romania expansion of agricultural land contaminated with oil residues and crude oil is estimated at 50.100 ha. (Dumitru et al., 2006) The main sources of pollution are oil extraction sector, the processing, transport and distribution of petroleum products.(Voiculescu et al, 2006). In Bihor

County, located in the west of Romania, historically contaminated with oil residues area is estimated at about 250 ha. The largest areas are found in the fields of oil production from Suplacu de Barcău, Marghita and Oradea. (Şandor, Sabău, 2007).

The crude oil from Suplacu de Barcău comprises a large percentage of heavy fractions, heavyy oils representing 40.1% and the asphaltins 35.3 %.The toxicity of the crude oil is amplified, also by the content of heavy metals, including cadmium that prevails, (483 ppm) iron (186 ppm) and nickel (40.5 ppm) (Sabău et al., 2011). The toxic effect of oil residues is felt by crop plants to quantities of pollutants exceeding 1 kg/m^2, i.e. 1 % oil residues on the plowed horizon of soil (Toti et al., 2003)

On soils polluted with crude oil are produced negative changes in the physical, chemical and biological properties. Between the physical properties of the soil, the aeration is most affected by the oil film formed on the surface, which hampered it aeration, so that the carbon dioxide content increases and reduces the oxygen content. Thus is affected the germination also crop growth and the microorganisms activity, respectively (Oyedeji et al., 2012)

Most affected chemical properties of polluted with crude oil soil are: increasing the total petroleum hydrocarbon (TPH) and total organic carbon (TOC), increasingthe ratio carbon/nitrogen (C/N), reducing the accessible phosphorus content,and sometimes, on the soil from extraction fields, where increased the content of soluble salts, due to salt waters on the deposit, being affected normal plant growth. (Marinescu et al., 2010)

Among the various technologies used today to improve cultivated soils polluted with crude oil, bioremediation of organic pollutants in the field, is most commonly used, especially for the lower concentrations of pollutants, because it is a method environmentally friendly and due to reduced costs, even if the necessary period is longer (Bijay et al, 2012)

Bioremediation of soils contaminated with crude oil is produced under natural conditions, the biodegradation of organic pollutants under the action of cultivated plants (phytoremediation) and microorganisms (bacteria, fungi, etc.) in the soil, reason why it is known as natural attenuation (Sabău et al., 2013)

To reduce the period of biodegradation the natural attenuation process is stimulated, through various agro pedo improvement measures, which aim: improving soil aeration through deep loosening work; correcting soil acidity by applying amendments; application of organic and mineral fertilizers to stimulate vegetative growth of plants and the equilibration of the carbon/nitrogen (C/N) report. (Glick, 2010; Kovacs, 2012)

Wang et al., 2013 demonstrates the remediation possibility of soils contaminated with crude oil, through phytoremediation, showing the reduction in time of the total petroleum hydrocarbons (TPH) content and changes in temperature and soil moisture, related to the concentration of initial pollutant and climatic conditions of the area.

Starting from the necessity for ecological restoration of soils contaminated with oil residues from Bihor, the Laboratory of Soil Science and Land Reclamation Station from Agricultural Research and Development Oradea, in 1993 is initiated the program "Research for the rehabilitation of degraded land with petroleum residue" compound of 3 experiences:1. Research on improvement of pseudogley albic luvisols, degraded soil with oil residues from petroleum production derrick in Suplacu de Barcău, Bihor County. 2. Microplot research on the influence of different doses of pollutant (oil residues) on soil and plants on brown luvic soil conditions from Oradea. 3. Microplot research on brown luvic soil regarding oil residues reduction from Oradea.The research was funded by the Research Institute for Soil Science and Agrochemistry Bucharest through the national program "Monitoring of the soil quality"(Şandor, 2011; Şandor et al., 2013)

The first research results from Oradea on the effect of under control pollution of a haplic luvosol, with different doses of crude oil brought from Suplacu of Barcău on yields, in the first two years of research on the yields have shown the reduction of millet hay yields, proportional to the doses size of pollutant (Colibaş et al, 1995);

Subsequent research conducted by Fagaraşi, 2011 confirms the biodegradation of petroleum residues, under the action of bacteria and fungi from the soil, for the conditions from Suplacu de Barcău, being identified 12 strains of bacteria from the genus:*Acinetobacter, Bacillus*(three strains), *Burkholderia* and species *Pseudomonas putida, Pseudomonas fluorescens, Burkholderia cepacia, Burkholderia gladioli* (two strains), *Enterobacter clocae*(two strains) and 12 fungal strains of the genera *Aspergillus*(five strains), *Acremonium, Crysosporium, Mortierella*(two strains) *Paecylomice*and two strains of *Penicillium*.

The partial results of research from Oradea, on soil phytoremediation by cultivating with millet and spring wheat (1996-2002) showed that the period of improvement is dependent on weather conditions (precipitation and temperature) during the vegetation season, which influence the activity of soil microorganisms (Şandor Maria, Sabău N. C., 2007; Sabău N. C., et al., 2009; Sabău N. C., et al., 2010).

In this paper we propose the analyze of the climatic conditions influence during the vegetation season of spring wheat on the yield losses due to soil pollution with crude oil,during the period ofenhancing natural attenuation, by applying a fertilization system with organic (manure) and mineral (complex fertilizers, NPK) fertilizers.

MATERIAL AND METHOD

Research on amelioration of polluted soils with oil residues from Oradea were conducted in the experimental field of Research and Development Station, on a haplic luvosil. The experience on amelioration of polluted soil with oil residue was placed in 1993 in the vicinity of the one concerning the study of different crude oil doses on soil properties and crops.

This experience is the type trifactorial (2 x 4 x 4) in Latin rectangle with subdivided plots, which are located in four repetitions, the microparcels having 1 m^2.The studied factors were:the factor A, with two graduations a_0, the control and a_1, polluted soil with crude oil, in concentration of 3 % (9 l/m^2) on plowed horizon; the factor B, organic fertilization with manure: b_0 - 0 t / ha, b_1 - 50 t/ha, b_2 - 100 t/ha and b_3 - 150 t/ha manure;the factor C, mineral fertilization with complex fertilizers in doses (kg/ha active substance) of: c_0 – $N_0P_0K_0$; c_1 - $N_{100}P_{80}K_{70}$; c_2 – $N_{200}P_{160}K_{140}$; c_3 – $N_{300}P_{240}K_{210}$.

The experience has been cultivated in the first three years of research with millet (1993-1995), which has high tolerance to pollution and then, in the next seven years (1996-2002) with spring wheat.

Soil type of the experimental field is characterized by colloidal clay content (< 0.002 mm) greater than 40 %, moderately acidic reaction (pH = 5.5) and low contents in humus and nutrients on plowed horizon (Sabău N. C., Şandor Maria, 2014).

For the analysis of the correlative links between the main climatic characteristics of the vegetation period of spring wheat and yield differences between polluted and unpolluted (control) variants were used data provided by the Meteorological Station Oradea, located near the experimental field.

The regression equations were determined using EXCEL program facilities, taking into account of the R^2 coefficient values, while their statistical significance was analyzed using ANOVA methodology, using Student t test for determining Least Significant Differences (LSD).For more safety the statistical significance of spatial correlation (3D) links was appreciated, in addition to by the F, Fischer test.

RESULTS AND DISSCUSIONS

The climate conditions of the studied period (1996-2002) are characterized by the registrations from Meteorological Station Oradea, where the multiannual average of rainfall is 635.0 mm and the air temperature is 10.5°C.,being rainier of 26.2 mm and warmer of 0.5°C than the normal (Table 1.)

Table 1

Climate characteristics of the research period\vegetation period of spring wheat
Oradea Weather Station (1996-2002)

Years	Annual				Vegetation period (III-VIII)		
	Rainfall (R)		Temperature (T)		R	T	de Martonne Index (dMI)
	(mm)	Diffe-rences	(°C)	Diffe-rences	(mm)	(°C)	(mm/°C)
1996	886.0	+224.8	9.6	-1.4	460.9	14.95	34.00
1997	710.4	+49.2	11.4	+0.4	481.8	15.83	34.04
1998	786.6	+125.4	10.3	-0.7	488.9	15.32	36.52
1999	827.7	+166.5	10.9	-0.1	429.6	16.30	31.61
2000	367.0	-294.2	12.0	+1.0	212.6	17.13	18.83
2001	830.6	+169.7	10.8	-0.2	536.6	16.38	43.97
2002	531.5	-129.7	11.9	+0.9	235.9	17.48	16.13
Average 1996-2002	661.2	+26.2	11.0	+0.5	406.6	16.02	30.74
Multiannual Average	635.0		10.5				

The vegetation period of the spring wheat, considered from March to August (III-VIII) is characterized by rainfall 406.6 mm, the average air temperature of 16.02°C and de Martonne aridity index values of 30.74 mm/°C.The extreme values of these indices were recorded in the years: 2001 and 2000, the rainfall, Rbeing 212.6 mm and 536.6 respective; 1996 and 2002 for air temperature, T (14.95 and 17.48°C); de Martonne aridity index, dMI presents the extreme values in the years: 2001, 2002 respectively 43.97 and 16.13 mm/°C.

The averages of yield differences between unpolluted (a_0) and polluted by 3% oil variants (a_1) varies inversely with the quantity of manure administrated and with the doses of complex fertilizers applied, being maximum in the absence of manure and complex fertilizer, of 1.86 q/ha and minimum in the case of maximum doses in complex and manure applied, becoming negative for 150 t/ha manure and $N_{200}P_{160}K_{140}$ (-0.03 q/ha) (Figure 1.)

The influence of climatic conditions during the vegetation period of spring wheat on yield differences between unpolluted and polluted variants, achieved by applying of organic fertilizer (manure), complex mineral fertilizer (NPK) systems and the cumulative effect of the two categories of fertilizers is highlighted by second degree polynomial correlations established (Table 2.)

These correlations are statistically significant (p = 0.1%) in the case of dMI, during the vegetation period, for mineral fertilizer system and cumulative fertilization. (R^2 = 0.6901 and R^2 = 0.6047 respectively)

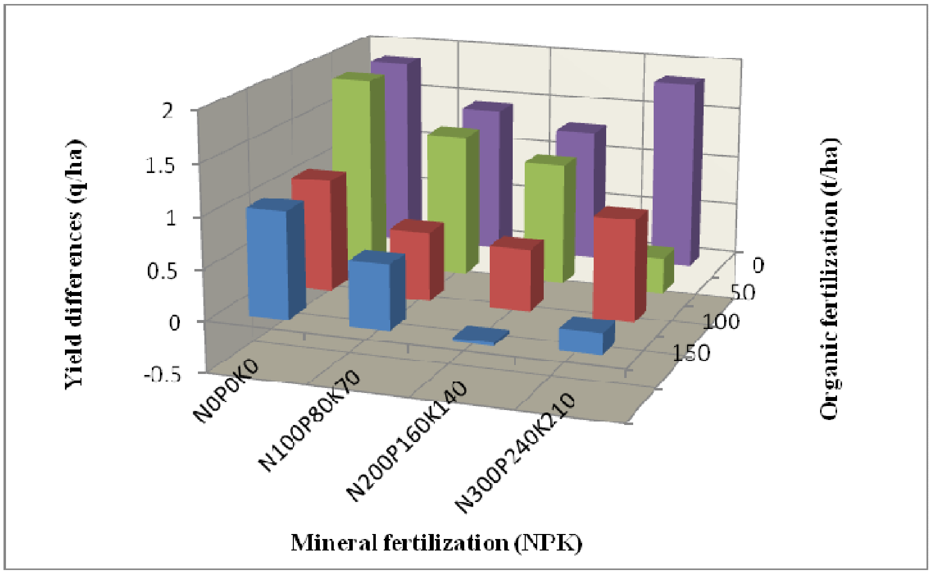


Fig.1. The average yield differences between unpolluted (a_0) and polluted 3 % (a_1) variants (q/ha)

Table 2

The correlations between the yield differences (YD, q/ha) of spring wheat ($a_0 - a_1$) and the main climatic characteristics from vegetation period (III-VIII)

Nb. of values pairs (n)	X	The equations	Correlation coeficient R^2	Statistical significance
Organic fertilizer (manure)				
28	R (mm)	$YD=-0.0001X^2+0.0965X-15.693$	0.4188	*
28	T (°C)	$YD=-0.2493X^2+6.4667X-37.68$	0.4707	*
28	dMI (mm/°C)	$YD=-0.0183X^2+1.1322X-14.492$	0.5880	**
Mineral Fertilizer (NPK)				
28	R (mm)	$YD=-0.0001X^2+0.0917X-14.805$	0.5252	**
28	T (°C)	$YD=-0.5356X^2+15.912X-115.22$	0.5346	**
28	dMI (mm/°C)	$YD=-0.0166X^2+1.0393X-13.278$	0.6901	***
Organic and Mineral fertilizer (manure+ NPK)				
28	R (mm)	$YD=-0.0001X^2+0.1109X-17.808$	0.4317	*
28	T (°C)	$YD=-1.03X^2+32.256X-250.28$	0.3475	-
28	dMI (mm/°C)	$YD=-0.0195X^2+1.1812X-15.079$	0.6047	***

For the other climate indicators used in our analysis, distinct significant (p = 1%) and statistically significant (p = 5%) correlations are established, except for the average temperatures influence on yield differences resulting from the application of organic and mineral fertilizers.

The curves shape of yield differences, according to the average temperatures of the vegetation period shows that both organic and for the mineral fertilization, yield differences are reduced with increasing of average temperatures (Figure 2.)

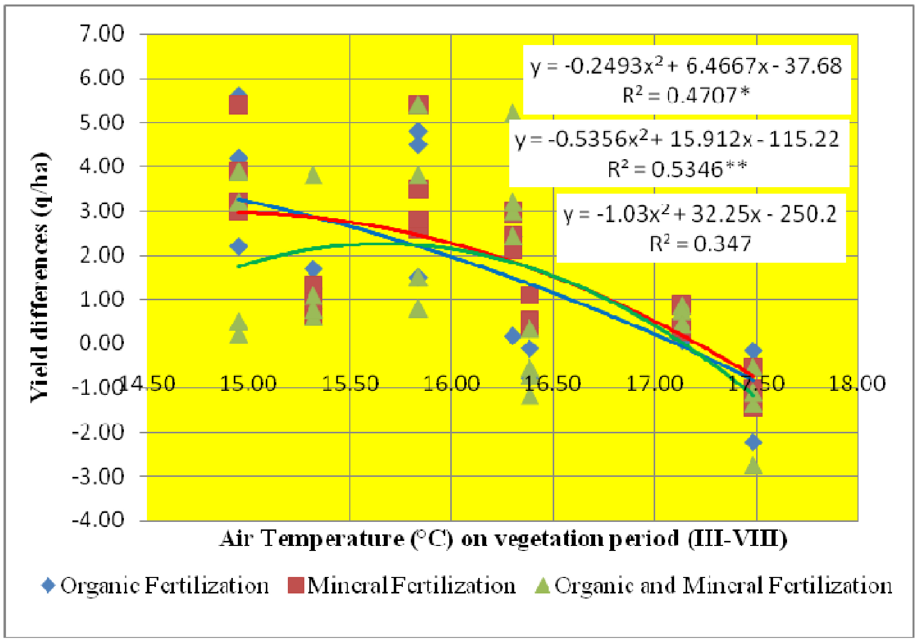


Fig.2. Influence of average air temperature of vegetation period (III-VIII) on yield differences (q/ha) of different fertilization systems

An exception is the curve without statistical backing of the link between the average temperature and the yield differences obtained in accordance with the organic fertilizer and minerals system, for which yield differences has a maximum between 15.5 and 16.0°C, after which these it reduces with increasing the average temperatures value.

The bifactorial, spatial correlations study (3D) between yield differences ($a_0 - a_1$) made of spring wheat (YD) and climatic characteristics of the vegetation period (X_1:rainfallR (mm); temperature T (°C) and thede Martonne aridity index dMI (mm/°C)) and the fertilization systems applied respectively (X_2: manure (100 t/ha), complex fertilizers ($N_{100}P_{80}K_{70}$) and organic plus mineral fertilization, without the interaction of the two factors, shows that in most cases are very significant statistically (Table 3)

The exception is the influence of temperatures (T) and quantities of manure and complex fertilizers doses (X2) on the yield differences of spring wheat, which after correlation coefficient (R^2 = 0.6301) is distinct significant statistically, while the F Fisher test indicates a very significant link; (p = 0.1 %) the calculated value Fc = 9.79 >table value F = 3.69.

Table 3

The bifactorial, polynomial second degree, yield differences (YD, q/ha) in function of climate characteristics of vegetation period (X_1) and fertilization doses administrated (X_2)

X_1	X_2	The equations	R^2	F_c	Signifi-cance
R (mm)	Organic fertilization	$YD=-15.2204+0.0965 X_1-0.0001 X_1^2-0.5666 X2-0.05429 X_2^2$	0.6715	11.75	***
T (°C)	Gunoi 0 = 0 t/ha	$YD=-37.2076+6.4667 X_1-0.2493 X_1^2-0.5666 X_2-0.05429 X_2^2$	0.7091	14.02	***
dMI (mm/°C)	0.5 = 50 t/ha 1.0=100 t/ha 1.5=150 t/ha	$YD=-14.0192+1.1322 X_1-0.0183 X_1^2-0.5666 X_2-0.05429 X_2^2$	0.7875	21.31	***
R (mm)	Mineral fertilization	$YD=-14.5329+0.0917 X_1-0.0001 X_1^2-0.7483 X_2+0.2429 X_2^2$	0.7377	16.17	***
T (°C)	0 = $N_0P_0K_0$	$YD=-114.949+15.9122 X_1-0.5356 X_1^2-0.7483 X_2+0.2429 X_2^2$	0.7441	16.72	***
dMI (mm/°C)	1=$N_{100}P_{80}K_{70}$ 2=$N_{200}P_{160}K_{140}$ 3=$N_{300}P_{240}K_{210}$	$YD=-13.0058+1.0393 X_1-0.0166 X_1^2-0.7483 X_2+0.2429 X_2^2$	0.8421	30.67	***
R (mm)	Organic and Mineral	$YD=-17.2736+0.01118 X_1-0.0001 X_1^2 -1.0871 X_2+0.1970 X_2^2$	0.6855	12.53	***
T (°C)	fertilization 0 = 0 x 0	$YD=-261.768+33.7842 X_1-1.0776 X_1^2-1.0871 X_2+0.1970 X_2^2$	0.6301	9.79	**
dMI (mm/°C)	0.5 = 0.5 x1 2 = 1 x 2 4.5 = 1.5x 3	$YD=-14.6661+1.2040 X_1-0.0198 X_1^2-1.0871 X_2+0.1970 X_2^2$	0.8005	23.06	***

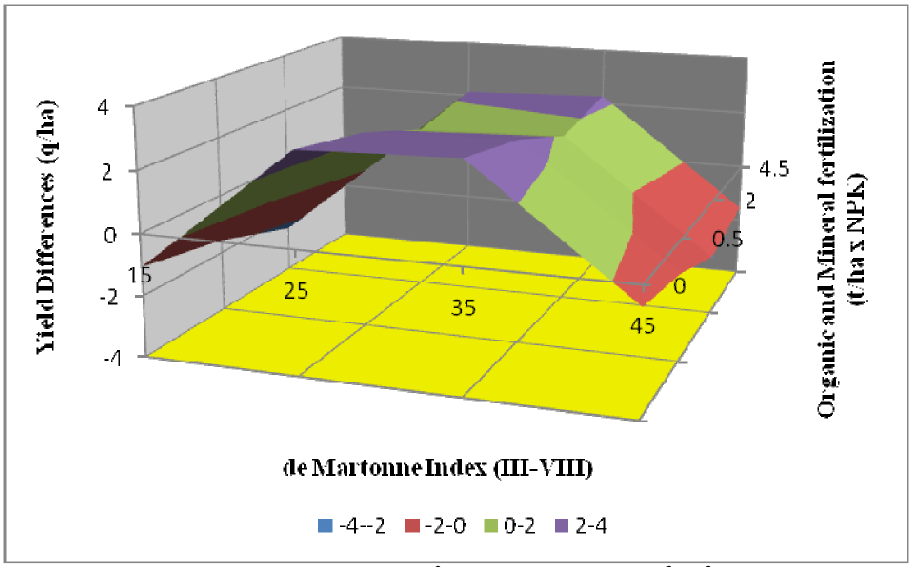
Analyzing the deducted equations it can be seen that the influence of rainfall on yield differences in the three systems of fertilization, is close to the linear,the term that indicate the influence of the squares rainfall is almost zero: a_{12} = 0.0001.The most important effect of precipitation is shown for organic fertilization system (a_{11} = 0.0965).

For temperatures, negative values of the term a_{12}indicate the reducing effect of yield differences with increasing squarestemperature. The highest values of the term a_{11} = 33.7842 are encountered in the case of combined fertilization system (organic + mineral).

Assessment of climatic conditions through de Martonne aridity index (dMI) shows similar effects to those temperatures, only the effects of reducing in yield differences being lower due to the influence of rainfall.

The compared study of the quantities effects of manure and complex fertilizers doses administered to the same climatic conditions highlights the superior behavior of combined fertilizer system, followed by mineral fertilization and then organic fertilizer.

The biggest differences in production, for fertilization systems analyzed were recorded for the de Martonne aridity index (dMI) values between 25 and 35, values which characterize the respective vegetation periods as being rainy to very rainy (Figure 3.)



*$YD=-14,6661+1,2040\,X_1-0,0198\,X_1^2-1,0871\,X_2+0,1970\,X_2^2$; $R^2= 0,8005$****

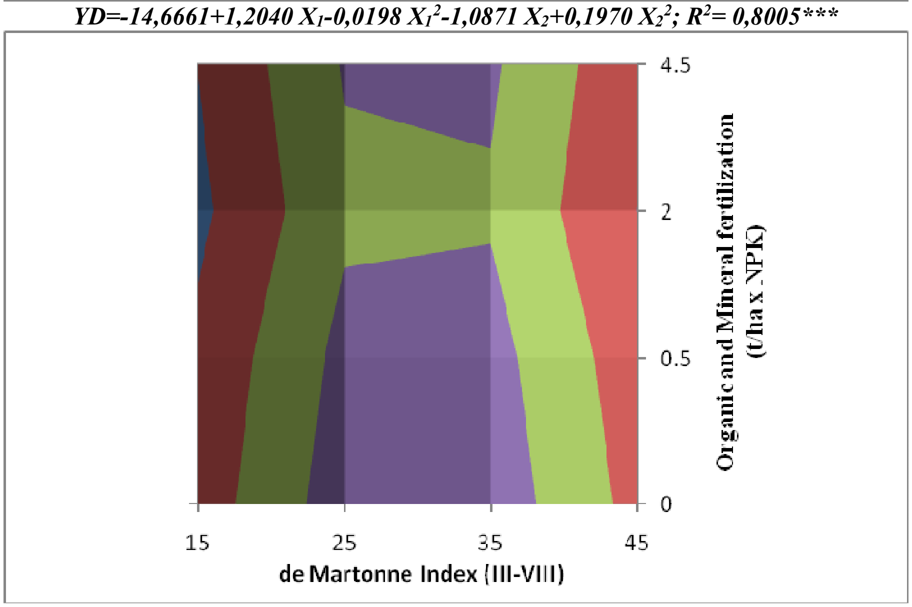


Fig.3. The response surface yield differences ofspring wheat depending on the de Martonne aridity index (dMI) values and manure plus NPK doses administered

It may also be noted, that most small yield differences, with negative values, irrespective of the fertilizer system applied, were in the final year of observations, characterized by dMI = 16.13, that indicate anexcessively dry vegetation period.

Small yield differences values, close to nil was recorded in 2001 (dMI = 43.97) when the vegetation period was excessively rainy, being affected the productions in both control plots and polluted plots.

Response surface of yield differences of spring wheat, according to the de Martonne aridity index (dMI) values and the doses oforganic plus complex fertilizers administered indicates that the smallest differences resulting to 100 t/ha manure + $N_{200}P_{160}K_{140}$.

If before these fertilizing levels the yield differences shows a decreasing trend, the increasing amounts of manure and complex fertilizers doses administered over this value, does not lead to a substantial reduction of differences.

Considering that the average yield differences of research period shows a decreasing trend in proportion with increasing amounts of manure managed and with increasing doses of complex fertilizers, less $N_{300}P_{240}K_{210}$ version, (Fig.1.) this suggests the possibility of an imbalance of the C/N ratio, which can have negative effects on microorganisms responsible for biodegradation of petroleum residues from the soil.

This hypothesis could be confirmed by the fact that the greatest yield differences were recorded from rainy to very rainy periods (3.04 to 3.18 q/ha in variant without fertilization) and the lowest in periods of excessively dry (-2.74 q/ha in the variant with maximum fertilization), when the soil is characterized by good aeration, favorable of biodegradation activity of specialized microorganisms from soil.

CONCLUSIONS

The climatic conditions during the conduct of the research (1996-2002) were characterized by annual rainfall amount of 661.2 mm, more rainy than the annual average of 26.2 mm and average annual temperature of 11.0°C, warmer with 0.5°C.

The yield differences between unpolluted(a_0) and polluted by 3% crude oil (a_1)variants, varies inversely with the administered quantity of manure and theapplied doses of complex fertilizer, being the maximum of 1.86 q/ha in the absence of fertilization,andminimum for maximum doses of manure and complex fertilizers applied, becoming negative for 150 t/ha manure and $N_{200}P_{160}K_{140}$ (-0.03 q/ha).

The polynomial of twodegree relations established between yield differences (q/ha) achieved by applying of organic, mineral (NPK) and combined fertilizersystems, respectively climatic conditions during the vegetation season of spring wheat are very significant statistically (p = 0.1%) in the case of de Martonne aridity index (dMI) for mineral (R2 = 0.6901) and combined fertilizer systems (R2 = 0.6047) respectively.

The correlative link established between the average temperatures of the vegetation period and the yield differences show that after a maximum reached between 15.5 and 16.0°C, the yield differences are reduced in proportion to the rising temperatures, irrespective of the applied fertilizer systems.

The bifactorial, spatial,polynomialsecond-degree correlations (3D) without interaction of the factors, very significant statistically,allow the simulation of yield differences according to the climatic indices analyzed and fertilizer doses appliedin the tested fertilization systems.

The influence of de Martonne aridity index (dMI) on the yield differences (YD) shows that regardless of the applied doses, the biggest differences is recorded during the periods from medium to rainy (3.04 to 3.18 q/ha, in the variant without fertilization) and the smallest, with negative values for dMI = 16.13, which indicates an excessively dry vegetation season.

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