CORELATIONS BETWEEN MILLET YIELDS REGISTERED ON A PRELUVOSOL POLLUTED WITH OIL AND THE CLIMATE CONDITIONS FROM ORADEA

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Abstract

The paper presents the results of the researches carried out at the Agricultural Research Station Oradea, Bihor county, between 1993 and 2002, regarding agricultural yield from a luvosoil polluted under control with oil brought from the exploitation site at Suplacu de Barcău, Bihor county

The experimental device was made out of micro parcels of 1 m², set up in a randomized manner, in a Latin square, polluted with a concentration of: 0, 1, 3, 5 and 10 % (0, 3, 9, 15, and 30 l/m²), oil in the ploughed layer, in 4 repetitions. The experience was than cultivated with in the first three years with millet, a plant wich is considered to be resistant to pollution, and than until 2002 with spring wheat.

By analyzing the correlations between the millet yield in the first 3 years of research and the climate factors (rainfall and air temperature) registered in the vegetation period, very significant square, polynomial correlations were established for each oil concentration.

The 3D representation of this presents for each concentration a technical maximum of yields at value of the optimum de Martone climatic index (IdM_{0pt}) of 30,35 mm/ºC. Analyzing the values of technical maximum yields of millet we can estimated the percentage of biodegadated oil.

Key words*:* oil pollution, climate conditions, preluvosoil, oil biodegradation

INTRODUCTION

The pollution of soil with oil residue is a very complex phenomenon that involves knowing the chemical nature and concentration of the pollutant and the soil conditions.

The extraction, processing and transportation of the oil products in the conditions of Bihor County took place at the oil plants in Suplacu de Barcau, Marghita and Oradea, today OMV centers and in the SC Petrolsub SA Refinery, in Suplacu de Barcau, today in preservation. Because of these activities the soil is affected by historical pollution, proxy. 200 ha are affected and are in need of measurements for ecological reconstruction.[3]

The researches carried out by Toti Mh and coworkers – 2003, on the effect of oil pollution on the agricultural land from the extraction locations form the Southern part of the country have shown that the plant's life is affected at a very mild pollution of 1 kg/m^2 (0,3 %) oil residue.[8]

For the conditions in Western Romania Colibas I., and coworkers publishes in 1995 the first partial results of researches regarding yield losses in millet, first year polluted with oil residue in controlled circumstances with various doses of oil. [1]Later Sabău N.C. and Şandor Maria – 2006, Sabău N.C. – 2007, Şandor Maria, Sabău N.C. and all. – 2007 publish the results of researches regarding yield of oil polluted plots that took place at the Agricultural Research Station in Oradea, and correlations between yield and the concentration of oil residue in the soil. [4,5,6,7]

MATERIAL AND METHODS

The researches carried out in Oradea had as an objective the study of the effects caused by oil residue from Suplacu de Barcau on agricultural yields, and on the time needed for biodegradation without any improvement measures.

Because 43,397 % of the total soil surface in Romania polluted with oil is made out of luvosoil and that the main type of soil at Suplacu de Barcau is the luvosoil, the experiment was set up on the preluvosoil from the Agricultural Research Station Oradea. [2]

The experimental field was set up in 1993 and is made out of micro parcels of 1 m^2, set up in latin square, randomized in four repetitions, polluted under control with oil from Suplacu de Barcău, with 0, 3, 9, 15 and 30 l/m^2, thus having the following concentrations with 0 in the ploughed layer (unpolluted witness), 1, 3, 5 and 10 %.

The field was cultivated with millet in the first three years (1993 –1995), a plant that has an increased tolerance to pollution and that for the next seven years (1996-2002) with spring wheat, Speranta breed.

After analyzing the agricultural yields obtained in millet (hay) and spring wheat have shown that the yield differences decrease in time without applying any corrective measures. They become insignificant after 7 years in the variant polluted with 1 % oil, after 8 years in concentration from 3 – 5 %, and after 9 years in the 10 % variant. This implies that the biodegration of the oil residue took place.

Starting from this observation this paper is commited to evaluating the influence of the climate factors, rainfall and temperature, on the biodegradation process, through the accomplished millet yields in the first three years of research.

RESULTS AND DISCUSSION

The climate conditions characterized by annual rainfall and temperature show that the 10 year period studied had with 26,2 m more rainfall than the annual average and was warmer with 0,5 ˚C.

The annual average agricultural yields of the unpolluted plots vary due to the climate conditions in the 3 years of research; they are smaller in the first year of crop (1993 – 17,6 q/ha millet hay), just to increase at 44,2 q/ha in the second year. The yields from 1995 are smaller than the ones in the previous year, but the 3,5 q/ha difference is insignificant. The yields of the variants polluted under control with oil residue have an increasing tendency, demonstrating a decrease of the effect pollution has on yield.

The millet hay (q/ha) – rainfall sum (mm) correlations from the vegetation period (May – August) are second degree polynomial, and look like $Y = aX^2 + bX + c$. (Figure 1.) The correlative links thus established are very significant for all the variants studied.

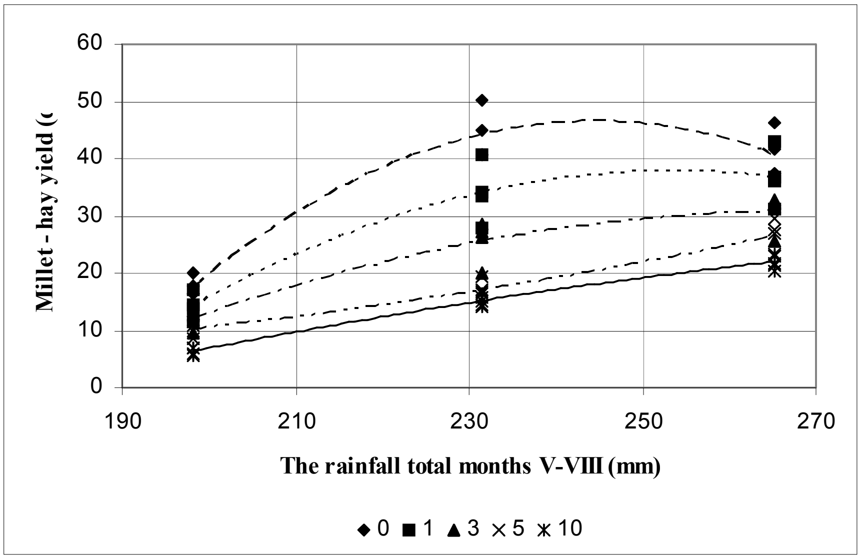


Fig. 1. The correlation between the millet hay yield and the total rainfall from the vegetation period.

The yields achieved by the variants polluted with oil more than 3 % increase with the increase in the rainfall. We can also notice that for the variants under controlled pollution the correlation coefficient that show the intensity of the bonds increase with oil dose administered. (Table 1.)

Table 1.

Polynomial second degree regresion equation
Millet hay yield (Y) – Rainfall during vegetation period (X)

Oil concentration (%)	Regression equation	Correlation coefficient	Meaning
0 (witness)	$Y = - 0{,}0135 X^2 + 6{,}6013 X – 760{,}68$	0,9317	***
1	$Y = - 0{,}0077 X^2 + 3{,}8991 X – 456{,}73$	0,8771	***
3	$Y = - 0{,}0037 X^2 + 1{,}9937 X – 237{,}7$	0,8930	***
5	$Y = 0{,}0011 X^2 – 0{,}2758 X + 20{,}887$	0,9210	***
10	$Y = -0{,}0009 X^2 + 0{,}6619 X – 88{,}486$	0,9778	***

The millet hay (q/ha) – average temperature (ºC) of the months in the vegetation period (Mai – August) are of the same type, polynomial of the second degree are also very significant. (Table 2.)

Table 2.

Polynomial second degree regression equation
Millet hay yield (Y) – Rainfall during vegetation period (X)

Oil concentration (%)	Regression equation	Correlation coefficient	Meaning
0 (witness)	$Y = - 18,888 X^2 + 669,21 X – 5882,4$	0,9317	***
1	$Y = - 9,755 X^2 + 339,41 X – 2915,3$	0,8771	***
3	$Y = - 3,8654 X^2 + 128,79 X –1040,9$	0,8930	***
5	$Y = 3,5091 X^2 – 138,4 X + 1,3347$	0,9210	***
10	$Y = 0,208 X^2 – 16,697 X + 247,88$	0,9778	***

The shape of the curves obtained for the witness variant and for the variants polluted with various forms of oil residue is similar with those for rainfall. The millet hay yield reduces as the average temperature rises. (Figure 2.)

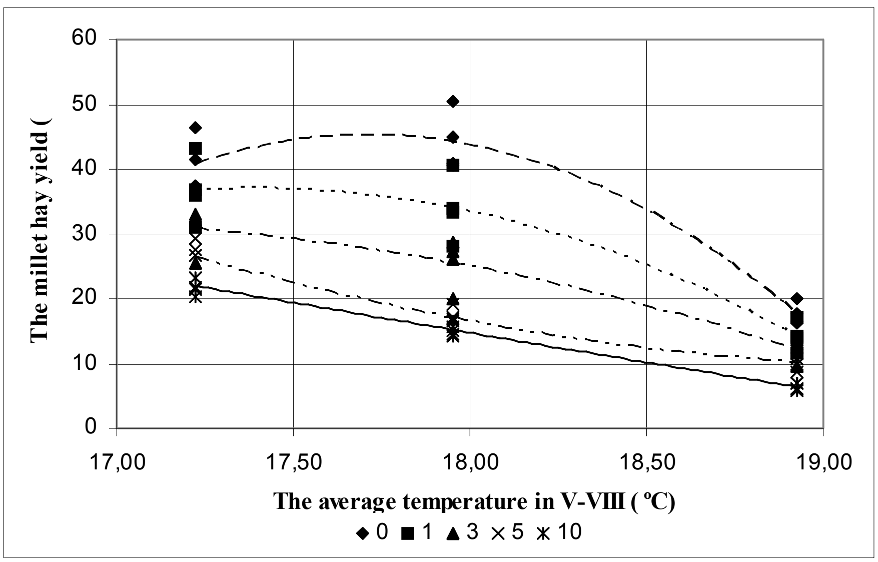


Fig. 2. Correlations between the millet hay and average temperature during the vegetation period

The second degree polynomial correlations with two factors and dependence between the factors studied. Seeing that the yields of variants polluted under control are in direct correlation with the sum of rainfall and the average temperature in the vegetation period, we tried to emphasize their influence on yields.

For the witness variant and the variants polluted in a controlled manner with oil residue second degree polynomial correlations were established, with two factors, and an interaction between the 2 factors, between average yield (Y) on one side and between the rainfall average sum (X_1) and average temperatures (X_2) from the vegetation period on the other side. (Table 3.)

Table 3.

Second degree regression equations, with two factors, with factor interaction
Millet hay interaction (Y) – Rainfall (X_1) and average temperature (X_2)

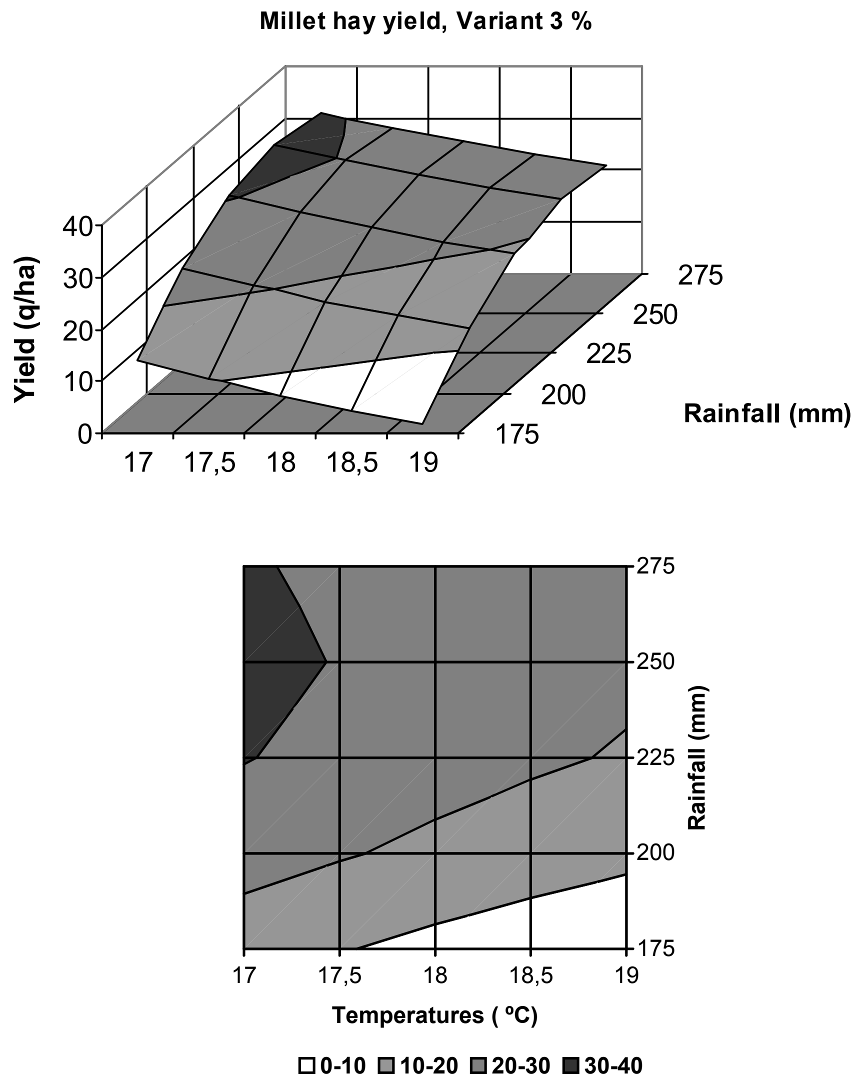
Oil concentration (%)	Regression equation	Correlation coefficient	Meaning
0 (witness)	$Y = 706,581 + 4,594\ X_1 - 0,011\ X_1^2 - 94,101\ X_2 + 1,716\ X_2^2 - 0,001\ X_1X_2$	0,9652	**
1	$Y = 266,808 + 2,801\ X_1 - 0,007\ X_1^2 - 59,628\ X_2 + 1,281\ X_2^2 + 0,036\ X_1X_2$	0,9365	**
3	$Y = 166,034 + 1,378\ X_1 - 0,003\ X_1^2 - 29,606\ X_2 + 0,591\ X_2^2 + 0,012\ X_1X_2$	0,9450	**
5	$Y = -116,144 - 0,280\ X_1 + 0,001\ X_1^2 + 6,284\ X_2 - 0,095\ X_2^2 + 0,017\ X_1X_2$	0,9456	**
10	$Y = -8,546 + 0,421\ X_1 - 0,001\ X_1^2 - 7,993\ X_2 + 0,177\ X_2^2 + 0,014\ X_1X_2$	0,9888	**

The links between the millet hay and the 2 factors taken into consideration is very significant for the two factors taken into consideration is very significant for the two variants studied, the correlation coefficient is 0,9652, and the polluted variants is between 0,9365 for the 1 % oil concentration and 0,9888 for the 10 % concentration we can see the tendency for growth with the rainfall increase.

After the space surface of the surface described by yields we can have 2 categories: the first category, representative for the witness variant and the ones polluted with 1 and 3 %, and with curves specific for the second category, specific for the variants polluted with 5 and 10 %, with shapes closer to a laniary one.

In order to show the 3D shape of the yields determined by the rainfalls and air temperature from the first category, the figure 3 shows the graphic variant for the variant polluted with 3 % oil.

For all the variants in this category, the polynomial second degree equation has the rainfall coefficient of the I order, a_{11} positive and the temperature coefficient I negative, the yields achieved grow in direct proportional with the rainfall and inverse proportional with the average temperature in the vegetation period.



$$Y = 166{,}034 + 1{,}378\, X_1 - 0{,}003\, X_1^2 - 29{,}606\, X_2 + 0{,}591\, X_2^2 + 0{,}012\, X_1 X_2$$

Fig. 3. The second degree polynomial correlation with 2 factors, Millet hay yield (q/ha) of the polluted variant with 3 % (Y) – Rainfall (X_1) and Temperature (X_2)

The second degree polynomial correlations with two factors between the millet hay (q/ha) - de Martone index and oil concentration. In order to study the links between the millet hay yields from the plots polluted under control and climate conditions the de Martone index was. This index has the advantage that it quantifies the influence of rainfall and temperature and can be calculated for the months in the vegetation period for millet hay, by using the formula [3]:

$$IdM = \sum_{V}^{VIII} \frac{12r}{t+10}; \qquad [1]$$

Where: IdM – the sum of de Martone index from the months V-VIII;
r – the sum of monthly rainfall (mm);
t – average monthly temperature (ºC)

The influence of the soil oil concentration and climate conditions on the millet hay yield a second degree polynomial link with 2 variables was established, very favorably. (Figure 4.)

The response surface of the average yield, depending on the 2 factors, show there is no codependency between the 2 factors, the oil concentration in the ploughed layer (X_1) and the values of de Martone (X_2) index.

We can see that the values of the de Martone index presented show that the values of the yield decrease by increasing the dose of oil initially applied. But, for the same oil dose, the evolution of the yields linked to the de Martone index is a second degree polynomial curve.

This shape of the curve allows to obtain the optimum de Martone index (IdM_{opt}), for which we get a yield maximum (Y_{max}) and the maximum level of the biodegradation process.

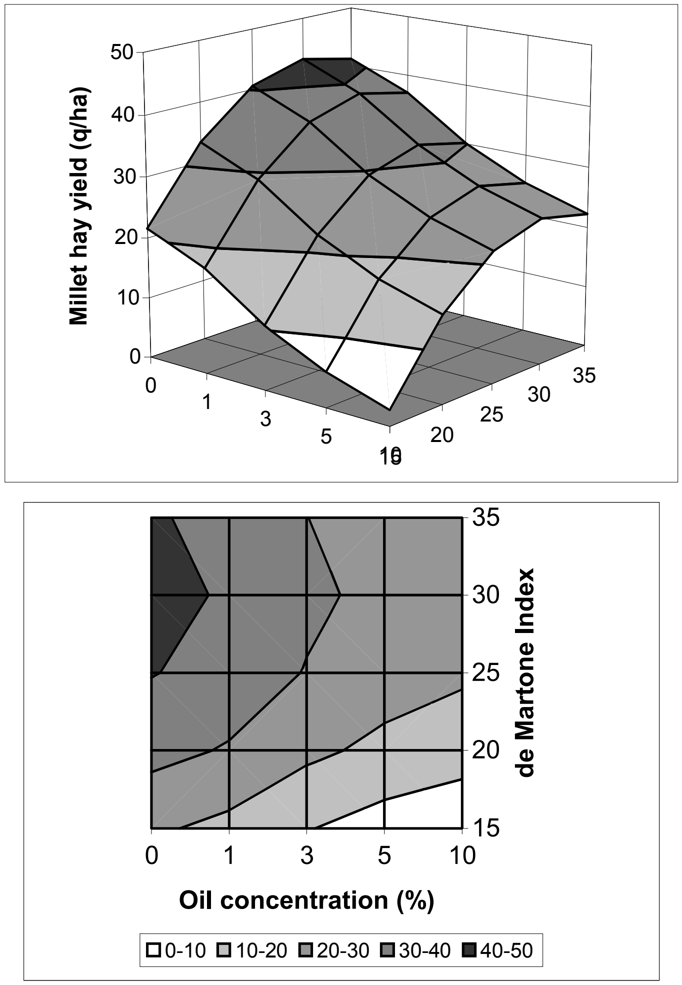
In order to obtain this we calculate the maximum value for the Y_{max}, thus canceling the first line of the function. According to this value, by solving the second degree equation we get IdM_{opt}. (Table 4.)

Table 4.

The calculation of the optimum values for the de Martone index

Oil concentration (%)	Equation $Y = a + b\ IdM + c\ IdM^2$	First line $Y' = -2c\ IdM + b$;	IdM_{opt}	Y_{max}
0	Y = - 41,2414 + 5,556768 IdM – 0,09154 IdM^2	-0.18308 IdM + 5.556768 = 0	30,35	43,09
1	Y = - 45,41093 + 5,556768 IdM – 0,09154 IdM^2	-0.18308 IdM + 5.556768 = 0	30,35	38,92
3	Y = - 52,23121 + 5,556768 IdM – 0,09154 IdM^2	-0.18308 IdM + 5.556768 = 0	30,35	32,10
5	Y = - 57,02645 + 5,556768 IdM – 0,09154 IdM^2	-0.18308 IdM + 5.556768 = 0	30,35	27,30
10	Y = - 60,155 + 5,556768 IdM – 0,09154 IdM^2	-0.18308 IdM + 5.556768 = 0	30,35	24,17

By analyzing the values calculated in the table up above we notice that for both the unpolluted witness and for the variants polluted with different concentrations we get values of $IdM_{opt} = 30,35$, for the de Martone index.



$Y = -41,2414 - 4,42266 X_1 + 0,25313 X_1^2 + 5,556768 X_2 - 0,09154 X_2^2; R = 0,962147;$

Fig. 4. Polynomial second degree correlation $Y=f(X_1, X2)$ between the millet hay yield (X_1) and the values of the de Martone index (X_2)

The maximum values of the average yield of millet hay are between 43,09 q/ha for the witness variant, and they decrease with the increase of the pollutant agent down to 24,17 q/ha for a concentration of 10 % oil.

Seeing that no organic mineral fertilizers were given, we can affirm that the yields come as a result from the biodegradation of the nutrients from the oil residue. From this point of view we would Y_{max} as an indicator of the intensity of the biodegradation, or as the intensity of the pollutant.

The maximum yields show a decreasing tendency, reducing once the oil residue concentration increases. For the witness variant the yield is not affected by the toxicity of the pollutant.

The minimum of the maximum yield is produced for the value of the concentration, it is achieved by canceling the first line of the function Y= f(X) and thus having an oil concentration of X = 8,74 %, close to the maximum 10 %. For this concentration the minimum yield is 23,32 q/ha.

Correlation between the millet–hay yields and annual de Martone index. If we analyze the polynomial second degree correlations established between the millet - hay yield (q/ha) of the 4 repetitions plots and the annual de Martone index, very significant correlations can be noticed for all pollution variants, they increase with the concentration in ploughed layer. (Figure 5.)

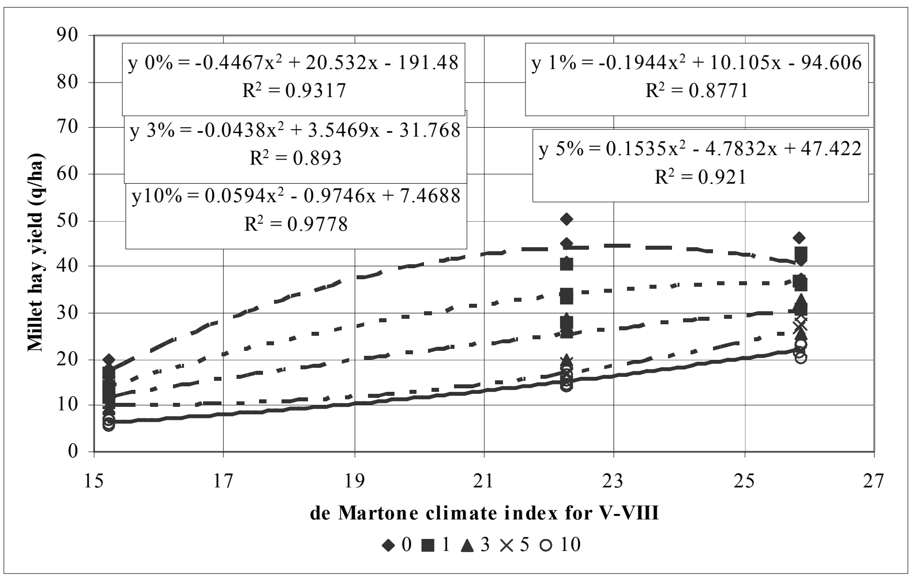


Fig. 5. Correlations between millet hay yield–de Martone climate index

Considering that for the initial witness variant, unpolluted the percentage of the biodegradation is 100 %, we notice that for a percentage close to 50 %, registered at 3 %, the shape of the curve is almost linear, for percentages bigger than 50 %, registered in the witness variant and the 1 % variant, the curves are concave, with a yield maximum, and for the variants with 5 % and 10 %, with the biodegradation process under 50 %, the shape of the curves is convex, with a yield minimum.

If we consider that the yield losses compared to the maximum are due to toxicity and the yields gains compared to the minimum are due to the nutrient intake from oil biodegradation, we can quantify the percentage oil biodegradation has.

The optimum values of the de Martone index (IdM_0), calculated when the first line Y' of function Y = f(x) is zero, are different from a variant to other. (Table 5.)

Table 5.

The maximum and minimum possible yields of the oil polluted variant.

Oil concentration (%)	First line Y'	IdM_0	Y_{max} (q/ha)	Y_{min} (q/ha)	Difference $Y-Y_{min}$	Biode-gradation percentage
0	-0,8934 X + 20,532 = 0	2,98	4,45		40,98	100
1	-0,3888 X + 10,105 = 0	5,99	6,71		33,24	81,11
3	-0,0876 X + 3,5469 = 0	0,49	0,04		36,57	89,24
5	+0,307 X – 4,7832 = 0	5,58		0,16	6,69	16,33
10	+0,1188 X – 0,9746 = 0	,20		,47	-	

For witness variant the maximum yield is 44,45 q/ha corresponding to optimum de Martone index IdM_0 = 22,98 mm/ºC. For the 5 and 10 % variant we have minimum yields, 10,16 and respectively 3,47 q/ha.

In the case of 1 and 3 % variants, when prevails biodegradation, a increase tendency, of the optimum de Martone index (IdMo) and possible maximum yields (Y_{max}) proportional to oil amount administrated, are registered.

The possible minimum yields (Y_{min}), where are characteristic to 5 and 10 % variants, are obtained for values of optimum de Martone index (IdM_0) of 15,58 and respectively 8,20 mm/ºC. This values have an inverse tendency in comparison whit the first variants, it decrease proportional of oil amount administrated.

By using the percentage of the yield gains due to biodegradation we can appreciate that in three years of millet cultivation, for the variant with 1 % pollution, 81 % of the initial quantity was degraded, at 3 % variant 89 % and at 5 % the process is in initial phase (16,3 %)

CONCLUSIONS

The second degree correlations very significant established from the millet hay yield (q/ha), for three years and the rainfall average and the rainfall sum and the average temperature in the vegetation period show that they are dependant on the climate conditions of the period studied.

The second degree polynomial correlations with the interaction of two climate factors very significant show that the the product between rainfall x temperature has a negative influence on the witnesses yield and a positive influence by determining the yield increase in all the variants studied.

The two factor second degree correlation, very significant, between the average yield of the polluted plots and the values of the de Martone index, and the concentration of pollutant show that the influences of the two factors on the yield are independent.

From the 3D presentation of the relation thus obtained, it resulted for all the polluted variants, the maximum intensity of the biodegradation process, by the means of technical maximum of average yields, is achieved for the same value of the de Martone $IdM_{opt} = 30,35$.

By assuming that yield losses are due to the toxicity of the pollutant that has not yet been biodegrade, and the yield gains compared to the minimum of maximum yields are realized due to nutrients in the biodegraded oil, we could determine the proportion of biodegrade pollutant in 3 years of crop without any agropedomeliorative measures.

By analyzing the shape of the polynomial curves of the second degree, very significant for annual yields, and the de Martone index we notice that for every variant that in the one polluted with 1 % and the witness variant the shape of the curve is concave, at the variant polluted with over 3 %, the biodegradation process is close to 50 %, the curve is almost a line, when for the 5 and 19 %, in which the biodegradation is under 50 % the curves are convex.

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