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WATER SOLUBLE PHOSPHORUS SOIL INSURANCE IN PLASTIC HOUSES CULTIVATED WITH VEGETABLE CROPS AND ACTIVE SUBSTANCE REQUIREMENT

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Abstract
The paper refers to a random survey, conducted in 11 Counties, important in vegetables growing in Romania, and around Bucharest, regarding to the actual phosphorus insurances of plastic house soils cultivated with vegetables. The study was conducted during the period 2002-2012, and a total of 497 of soil samples on the depth of 0-30 cm, were analyzed. It was found a relatively increasing trend of fertility until 2009, after which the concentrations of phosphorus in water-soluble forms, have fallen. Concentration of water soluble phosphorus has a mean value (17 mg·kg^{-1}*), on a mean textured soils. On the basis the plastic house soil contents P (water-soluble forms), average fertility status of soils in our plastic houses cultivated with vegetables, crop structure, mainly, in 2 cycles (early spring tomatoes and autumn cucumbers) or in one extended cycle (sweet peppers and eggplants), a total taken up of phosphorus and the average coefficients of fertilizers use, it was calculated an approximate necessary of active ingredient (*P_2O_5*) for an area of about 7,500 hectares of plastic houses (the year 2014) namely, *P_2O_5* 1,425 t. This means a consumption of *P_2O_5* of 190 kg·ha*$^{-1}$*·year*$^{-1}$*.*

Keywords: plastic houses, soil water soluble phosphorus, approximate necessary P_2O_5.

1. INTRODUCTION

In a previous paper we affirmed that vegetable cultivation in plastic houses is a real alternative for vegetable growing in Romania (Lăcătuş and Scurtu, 2014). Generally, protected crops are considered to be the best and cheapest insurance against climate damage (Boulard and Antipolis, 2005; Lăcătuş, 2008; Lăcătuş and Cârstea, 2012). Climate change for many years onwards, characterised by a prolonged drought combined with very high temperatures (Sandu and Mateescu, 2012), sometimes turned the cultivation of vegetables in the open field, in a real "adventure" (Lăcătuş et al., 2012). Lately, for example, to ensure the consumption of tomatoes from field crops has become a national problem. Many producers have given up. And not only from this crop! The area cultivated with vegetables has declined gradually from approximately 235,000 hectares to perhaps 150,000 hectares (Lăcătuş, 2013; Scurtu and Lăcătuş, 2013; Lăcătuş et al. 2013). In this context, is a safe solution the plastic houses for the development of a sustainable vegetable growing (Boulard, 2008; Scurtu and Lăcătuş, 2013).

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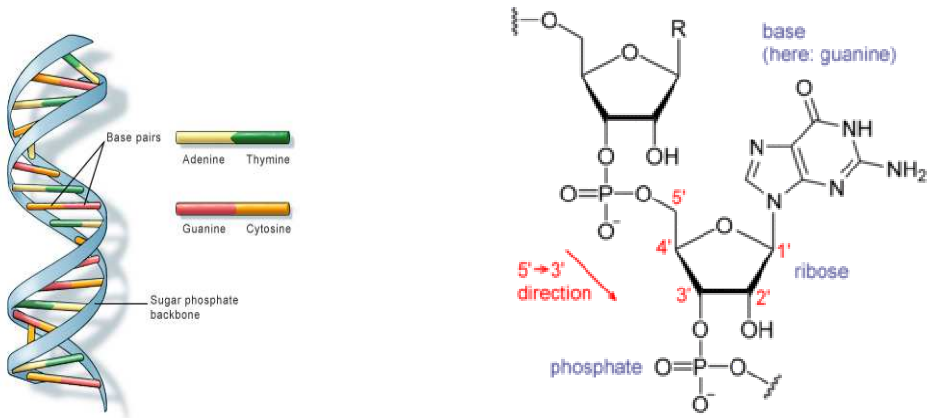

Figure 1. DNA and RNA forming blocks of life and phosphorus is a major component that feeds the functions of RNA synthesis of protein

Growing vegetables in protected system involves also additional costs (Voican and Lăcătuş, 2001; Cantlife and Vansickle, 2009). It's construction, the plastic film and last but not least cultivated biological material. While hybrids use are high performance: very early and very productive. To put the value these qualities, it is necessary to practice an appropriate technology. It is necessary, inter alia, as to have a soil fertility condition very good. This, of course, translates into a much higher consumption of fertilisers, for both the creation of an optimal level of nutrients in the soil and to cover consumption items, those taken up by plants. From this point of view, phosphorus may play a determining role. And not only for its importance in nutrition and metabolism of plants but also due to environmental conditions, the spring crop cycle, characterized by low temperatures. The only way to get this plant nutrient, energy planning, is to absorb it from the soil. Soils poor in PHOSPHORUS leads to poor plant in RNA and the possibilities of growth of plants. These plants have a less deeply root system, seeds are get out of shape, fruits are misshapen and discoloured leaves, fruits, and generally the whole plant is thin, poor feeds. RNA and DNA forming blocks of life and phosphorus is a major component that feeds the functions of RNA synthesis of protein (figure 1). Here are some of the associated effects of applying phosphorus: well developed root system; increase the number of root nodules; increases the average weight of bulbs; helps to grow lateral shoots; extended vegetation; prevents premature dried of the leaf; decreases the period of maturation; increase the number of flowers and the % of setting; increase early production; decreases the sensitivity of plants to: *Alternaria*, *Botrytis*, *Fusarium*, *Phytophtora* and *Erwinia*; protected plants against to *aphids* attack.

Figure 2. Tomato plant with phosphorus deficiency

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In a previous experiment, (Podoleanu et al., 1989; Podoleanu, 1999), it was revealed the role of phosphorus in the production of tomato seedlings. So, the authors get the maximum values for:

- leaf area (LF), 260 ± 59 dm^2/m^2, at 1 kg P_2O_5/m^3 growing substrate;
- dry matter weight (DMW), 670 g/m^2, at 0.75 kg P_2O_5/m^3 growing substrate;

Regarding development index (DI), calculated as the ratio of the weight of the dry matter and leaf area, it was found that the highest value, 284.65, was recorded at dose of 0.75 kg P_2O_5/m^3 growing substrate. Also we can calculate the following correlations:

- DMW (g/m^2) = P (in $mg\cdot kg^{-1}$)/($7.811\cdot 10^{-2} + 0.192\cdot 10^{-2}$ P), where $R^2 = 0.884^{**}$;
- DI (g DMW/m^2LF) = $(10.9 \cdot 10^3 + 0.494 \cdot 10^3\ P – 1.4\ P^2)^{1/2}$, where $R^2 = 0.59^{**}$.

The phosphorus in the above relations is expressed as water soluble form, with a rate of water and growing media of 1:10 (w/w).

2. MATERIALS AND METHODS

In the Research and Development Institute for Vegetables and Flowers Growing (RDIVFG), operates a laboratory of Agrochemistry, Biochemistry and Physiology, which performs analysis of agrochemical soil fertility status in order to establish it. Benefiting from a project in the framework of ADER (ADER, 3.1.2), we performed analyses and interpretation of soil samples, carried out over a period of 11 years (2002-2012). Soil sample was made up of 15-20 polls, and harvesting depth was of 25-30 cm. Normally was collected one soil sample from a solar area of which has varied between 200 and 1000 m^2. If there have been several plastic houses, number of soil samples depended on:

- uniformity of plastic houses; if they are relatively uniform, as soil type and as age, was harvested throughout a single sample, also from about 20 polls; for example, if there were 3 plastic houses next to each other, very similar, the soil sample was made up of 7 polls conducted in each plastic house;
- if the plastic houses are different, have different samples taken in each one and labelled accordingly;

The method of analysis used as extractant distilled water, and the rate of extraction soil : water was 1: 2.5 w/w (WE 1: 2.5), when the organic matter (OM) content of soil was under 6.5 %, and 1:5 w/w (WE 1:5), when OM was higher than 6.5 %. The analysis was conducted in fresh soil. By using this method is that it determines the actual fertility of soils. In this way has been given greater importance to intensity factor vs. capacitance. Thus, we believe that the determinations are more suitable for vegetable crops in plastic houses, intensive crops and sometimes even super intensive, as is the case of the heated crops.

Interpretation of soil analysis results was done on the basis of the interpretation of the laboratory of Agrochemistry, Biochemistry and Physiology of RDIVFG and which will take account the content of organic matter of the soil (Ghidia et al., 1972, 1973; Lăcătuş, 2006). This system uses the correlation between the content of organic matter and soil water field capacity (WFC):

$$\text{WFC}, \% \approx 2\cdot \text{OM}(\%) + 15$$

Relationship (2·OM(%) + 15) is considered to be equivalent to soil water field capacity, when it does not exceed 6.5 % content of OM. Because this dosage of organic matter is affected by some positive error due to the fact that the mineral portion of soil block loose and something in the constitution water, the above formulas reach limit values of their respective indices somewhat increased. However, the presence of mineral colloids in soil is likely to reduce the adverse effect of the high concentration of salts on plants, thus offsetting the error from the determination of the content of organic matter through incineration. In the case of soils with organic matter content

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higher than 6.5 %, the correlation between this and the soil water field capacity is described by the relation: WFC ≈ 2.7·OM (%) + 10.7 (Lăcătuş et al., 1979; Lăcătuş, 2009 a and b).
For water soluble phosphorous strength, if the soil organic matter content is higher than 6.5 %, appreciation is based on its texture. If the soil has a content of organic matter less than 6.5 %, the assessment does not take into account soil texture (table 1).

Table 1. Status appreciation of soil water soluble phosphorus from plastic houses with vegetables

Plastic house soils, $mg \cdot kg^{-1}$, in WE 1:5			Plastic house soils, $mg \cdot kg^{-1}$		Appreciation
Light texture	**Medium texture**	**Havy texture**	**In WE 1:2.5**	**In AL*,** (corrected)	
Under 17.5	Under 10.9	Under 8.7	Under 4.4	Under 100	Low
17.6 – 26.2	11.0 – 17.5	8.8 – 13.1	4.5 – 8.7	100 - 177	Medium
26.3 – 39.9	17.6 – 26.2	13.2 – 17.5	8.8 – 17.5	178 - 252	Normal
Over 39.9	Over 26.2	Over 17.5	Over 17.5	Over 252	High

*) AL: ammonium acetate lactate;

Following the data submitted by the Monitoring System of soil phosphate from Romania, it is noticed that the mobile phosphorus status (in AL) has a frequency of 86.68 % in extremely low-medium classis (table 2).

Table 2. Romanian Monitoring System of soil mobile phosphate (P_{AL})

Content class	Class limits, $mg \cdot kg^{-1}$	Frequency, %
Extremely low	Under 4.0	11.96
Very low	4.0 – 8.0	21.02
Low	9.0 – 18.0	33.00
Medium	19.0 – 36.0	20.70
High – very high	37.0 – 72.0	13.32

Comparing the two tables above, it can be seen as the optimum concentration of mobile phosphorus for vegetable crops from plastic houses is much more than a very high class (from 178 to 252 $mg \cdot kg^{-1}$ vs. 72 $mg \cdot kg^{-1}$)
Water soluble phosphorus (P) was determined by reaction with molybdenic reagent (after Troug-Meyer) in the presence of a reducing agent such as $SnCl_2$ and measured to SPECORD 205 spectrophotometer at 620 nm. The results were expressed in $mg \cdot kg^{-1}$ at the soil dry at 105 ° C.
The data analyzed in this paper come from 11 Counties and from Bucharest. It should be noted that this is not a systematic study but one randomly, but that can give us, through the multitude of soil samples analysed, namely 497 and certain correlations, indicative information regarding fertility status and especially the need for phosphorus fertilizers of this vegetable sector.

3. RESULTS AND DISSCUTIONS

Soil samples analyzed come from Counties of Buzău, Călăraşi, Dâmbovița, Galați, Giurgiu, Ialomița, Ilfov, Olt, Prahova, Teleorman and Tulcea, as well as in Bucharest. It is found that the areas are included in Romania's importance in the cultivation of vegetables, less the areas in the West and Northwest of Romania and North of Moldova.

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Dynamic evolution of the soil phosphorus content in all tasted areals

In table 3 we present the mean concentrations of phosphorus, in dynamics for the period 2002-2012, in all of the 11 Counties and Bucharest.

Table 3. Medium values dynamic of main actual phosphorus status of plastic house soils in 2002-2012 period (mg·kg^{-1})

YEAR	P_{H2O}	Number of samples per year
2002	24.6	7
2003	23.0	3
2004	26.1	53
2005	10.9	70
2006	9.4	108
2007	11.1	80
2008	14.1	43
2009	20.7	67
2010	17.9	32
2011	23.8	21
2012	8.5	13
Mean value ± sd	17.3±6.7	45±34
Maximum value	26.1	108
Minimum value	8.5	3

A graphical representation of the evolution of water soluble phosphorus concentration from soils (fig. 3) shows a decrease from 2002 until 2005, after which there is a slight increase in 2009, followed by a new decline towards 2012. There is generally a decrease over time, with a plateau between years 2004 and 2009.

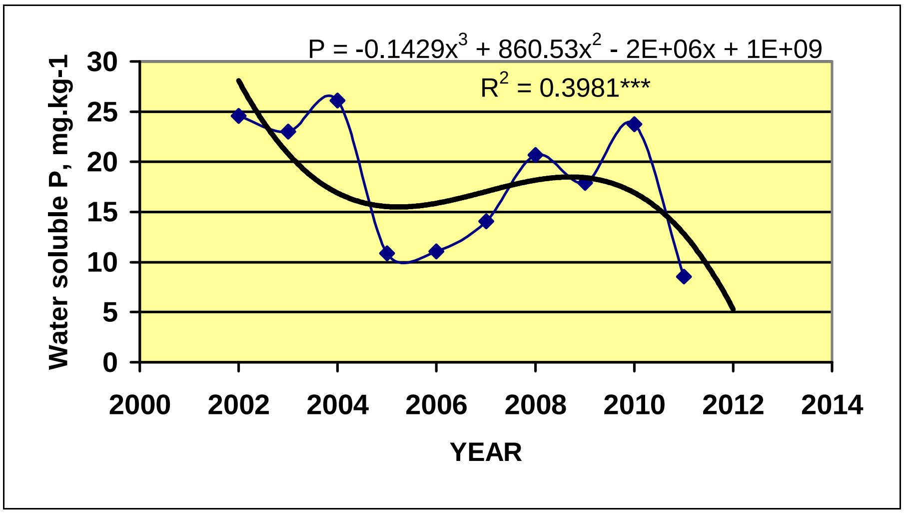

Figure 3. The evolution of water soluble phosphorus concentrations

We believe that these decreases contents of P in soils of plastic houses, after 2009, is due to both the effects of the economic crisis that has affected the purchasing power of farmers, the problems of superphosphate factories and increase areas of plastic houses, which meant taking into operation of new lands. Due to the large number of samples (497), the correlation coefficient is very significant.

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Next, we will examine in more detail the situation in some Counties: Giurgiu, Ilfov and Galati.

The actual soil fertility status of plastic houses from Giurgiu County

Within this County, in which vegetable has a significant importance, were analyzed for the period 2004-2012, a number of 181 soil samples. Registered average values are shown in table 4.

Table 4. The evolution of actual soil phosphorus status of plastic houses from vegetable area in Giurgiu County (mg·kg^{-1})

YEAR	P_{H2O}	Number of samples per year
2004	27.0	13
2005	11.4	26
2006	8.0	48
2007	12.6	34
2008	8.2	19
2009	20.2	13
2010	18.3	12
2011	28.5	10
2012	13.2	6
Mean value ±sd	**16.4±7.6**	**20±14**
Maximum value	**28.5**	**48**
Minimum value	**8**	**6**

Plotting this trend (figure 4) it is observed that after 2004, the concentration of soluble phosphorus in the soil decreases relatively until 2008, after which we noted an increasing trend.

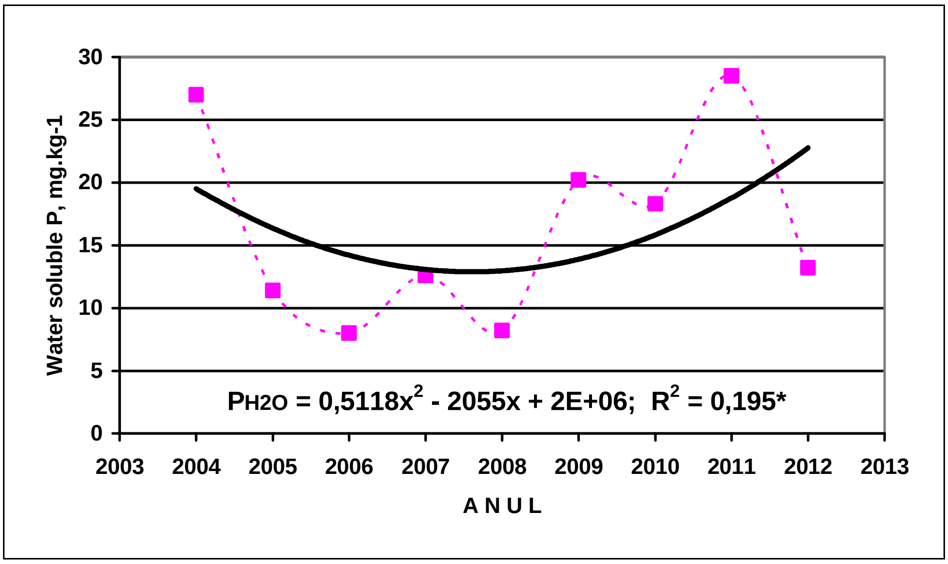

Figure 4. The dynamic of water soluble phosphorus concentrations in plastic house soils from Giurgiu County

The correlation index calculated using an equation Grade 3, describing the evolution closer to the analytical data, has a significant coefficient.

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The actual soil fertility status of plastic houses from Ilfov County

lfov County is also known for specialising in vegetable crop ponds in plastic houses. In this County for the period 2004-2012, 150 were analyzed soil samples. In table 5 are presented recorded average values for the contents of P, determined in water extract.

Table 5. The evolution of actual soil phosphorus status of plastic houses from vegetable area in Ilfov County ($mg \cdot kg^{-1}$)

YEAR	P_{H2O}	Number of samples per year
2004	18,7	12
2005	14,0	27
2006	11,0	35
2007	12,0	17
2008	27,0	14
2009	30,0	22
2010	20,0	13
2011	24,0	6
2012	7,0	4
Mean value ± sd	**18±8.0**	**17±10**
Maximum value	**30**	**35**
Minimum value	**7**	**4**

In table 4 it can find that water soluble phosphorus with 18 ± 8.0 $mg \cdot kg^{-1}$ is normal.

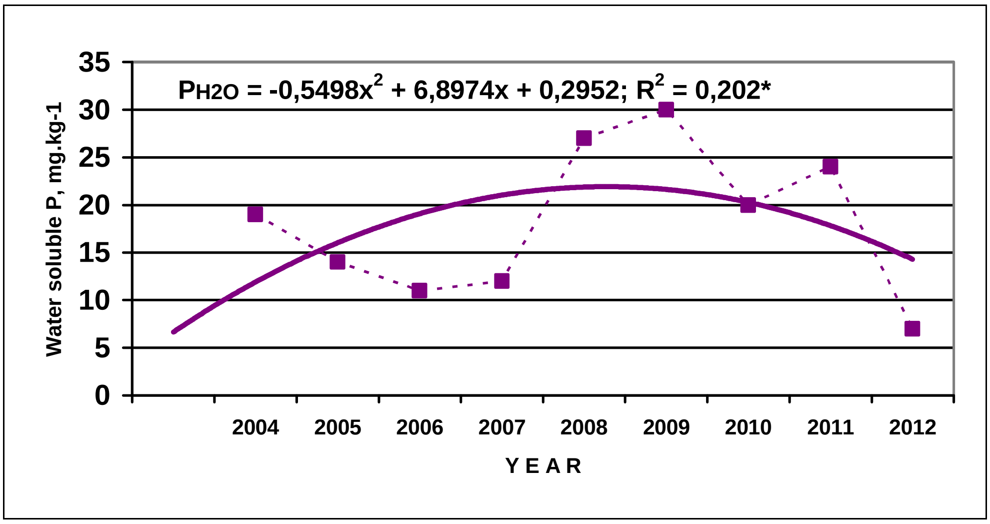

Figure 5. The dynamic of water soluble phosphorus concentrations in plastic house soils from Ilfov County

Graphic representing the evolution of soluble phosphorus concentration determined in samples of plastic houses from Ilfov County, we find that it is opposed to Giurgiu County. Namely, the concentration of phosphorus increases slightly from 2004 to 2009 and then begins to decline. The correlation coefficient also is significant. The explanation of this trend of curve comes from increasing area of plastic houses in this county to supply with vegetables the markets of Bucharest.

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The actual soil fertility status of plastic houses from Galati County

In Galati County, the County in which it is one of the most important vegetable area, Tecuci, pools with the Matca, the most representative for the cultivation of vegetables in plastic houses and where most samples originate, it is found that the average values of the water soluble phosphorus, are slightly higher. Thus, it has a higher average level, namely 21 ± 7.2 $mg \cdot kg^{-1}$ (table 6). In total, in this county we analyzed a number of 50 samples.

Table 6. The evolution of actual soil phosphorus status of plastic houses from vegetable area in Galati County ($mg \cdot kg^{-1}$)

ANUL	P_{H2O}	Number of samples per year
2002	24.6	7
2003	23.0	3
2004	29.0	6
2006	28.0	2
2007	21.1	9
2008	7.3	10
2009	20.1	12
2011	14.0	1
Mean value ± sd	**21±7.2**	**6±4**
Maximum value	**29**	**12**
Minimum value	**7.3**	**1**

During the years 2002 - 2012, water soluble phosphorus, easily accessible to plants, has more of a tendency of decreasing of the concentration (regression coefficient of 0.413 is distinct significant, figure 6).

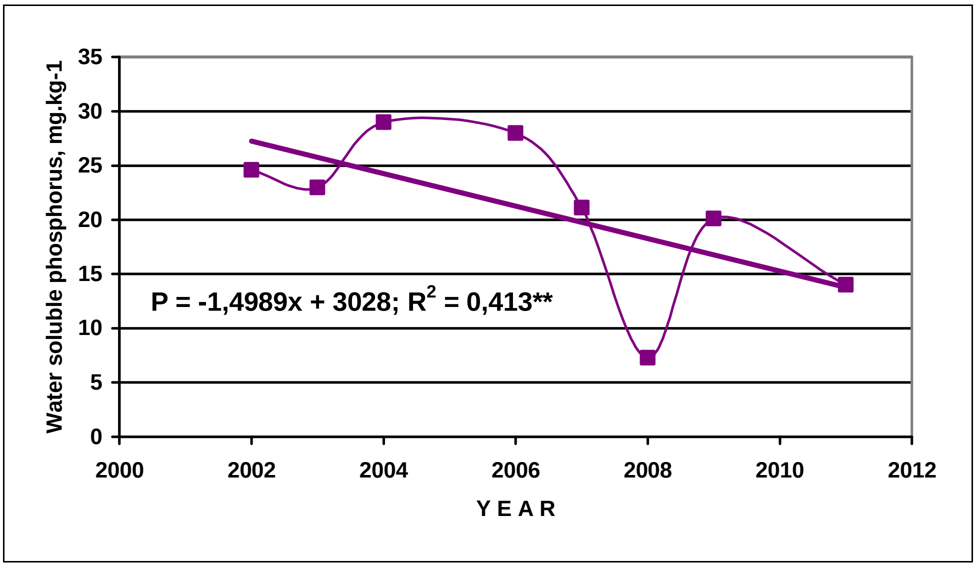

Figure 6. The dynamic of water soluble phosphorus concentrations in plastic house soils from Galati County

Within that area, it was determined the concentration of soluble salts. It ranged between 0.09 and 0.421 %, with an average of 0.22 %, against the background of an average insurance with organic matter of 9.3 %. Increased concentration of soluble salts in the soil solution in soil samples

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collected mainly from the Matca basin, Tecuci, Galati, is due to increased concentrations of nitrate nitrogen and water-soluble potassium (up to 178 and respectively 265 mg·kg^{-1}). The trend of increasing of both elements, nitrogen and potassium, is statistically assured (0.7 for N-NO_3 – distinct significant and 0.534 for K – very significant).

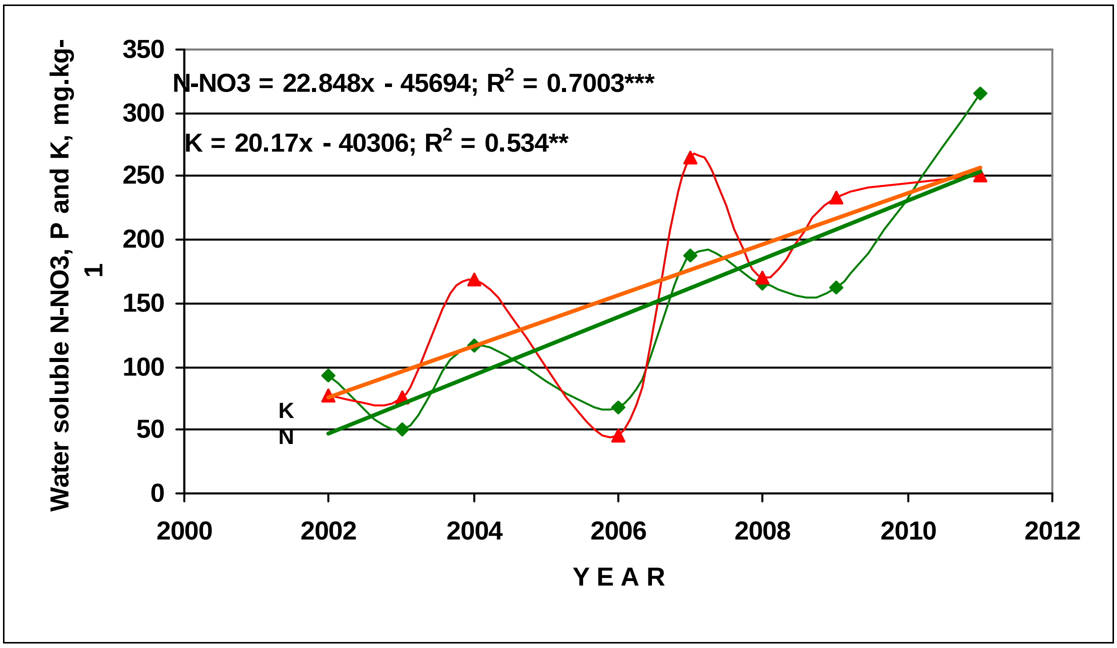

Figure 7. The dynamic of water soluble nitrate nitrogen, and potassium concentrations in plastic house soils from Galati County

The approximate appreciation of active substance requirements for vegetable crops from plastic houses

Based on the assessment of soil cover insurance with phosphorus in water-soluble form (table 1), the average situation of soil phosphorus status of our plastic houses cultivated with vegetables (table 3), the structure of crops in 2 cycles per year (tomatoes and cucumbers) or in one extended cycle (bell peppers and aubergines), from the total consumption of major elements (table 7) and from the average coefficients of utilization of fertilizers, we have calculated a necessary indication of active ingredient for an area of about 7,500 hectares plastic houses (the year 2014):

- P_2O_5: 1,425 t with a mean consumption of 190 kg·ha^{-1}·year^{-1};

Table 7. Total P taken up by mean vegetable crops cultivated in plastic houses

Vegetable crop	Yields t·ha^{-1}	P, kg·ha^{-1}
Sweet peppers	40-50	60
Cucumbers	50-80	56
Redish	15-20	35
Lettuce	15-20	16
Tomatoes	50-70	65
Eggplants	40-50	70

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Drip irrigation extension, including fertigation and thus the use of soluble, complex fertilizers can reduce the quantities of active ingredient from above, with 20-30 % (Lăcătuş and Cârstea, 2006; Sezen et al. 2006).

The value obtained seems to be great at first glance and is in contradiction with the statements of individuals, as well as in vegetable production and especially in plastic houses, would apply excess fertilizers. But the situation is not so. This confirms the yealds that we realize. As a rule, they are less than 3 to 4 times compared to the Netherlands and 2 times less than that in Spain, at the same crop time (Castilla and Leonardi, 2010; Costa and Heuvelink, 2000; Baudoin, 1999). Mention that in this article we presented the average values obtained. These averages, however, hide the minimum up to 1 $mg \cdot kg^{-1}$ for phosphorus concentration in aqueous extract.

4. CONCLUSIONS

Although this study has a random character, may be off a few conclusions:

- in general, after a relatively increasing trend, after 2009 the concentrations of phosphorus in the water-soluble forms in soil, have decreased;
- evolution of the status of actual fertility of the soil is relatively different from one area to another;
- average values of the 497 of soil samples analyzed, revealed a medium value insurance with water soluble phosphorus (17.3 ± 6.7 $mg \cdot kg^{-1}$) on a medium textured ground;
- to target requirements: P_2O_5 190 $kg \cdot ha^{-1} \cdot year^{-1}$.

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