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Ecological problems and nitrogen balance in vegetable crops growing

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Abstract

The purpose of this study is to focus on the nitrogen balance and losses in agricultural system. The influence of precipitation, irrigation and fertilizer application on some soil parameters, N-uptake by plant production and N-output by lysimetric water are evaluated in this paper.The study is carried out on Fluvisol, near Plovdiv in Southern Bulgaria under the conditions of field experiments with different vegetable crops (eggplant, green beans and carrots) over the period 2009-2011. The experimental design includes 3 treatments with nitrogen application –N_0, N_{80} and N_{160} on the background of $P_{80}K_{80}$ kg.ha^{-1}. The field plots are equipped with modification of Ebermayer type of lysimeters, which collect water from 100 cm depth of soil profile.According the received data it was observed that compensation between the amounts of N input and output was achieved in two variants (N_{80}, N_{160}) for all crops growing. Reducing the nitrogen input to the amount applied by precipitation and irrigation waters is the most ecological-friendly technological decision and very important factor for environment protection.

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Introduction

The nitrogen is one of the most important components in plant nutrition and therefore obtaining high yields to a large extent depend on the nitrogen fertilizers application (Raikova et al., 1996; Tilman et al., 2002). In the intensive farming of vegetables, the imported nitrogen fertilizer for different reasons can not reach an their main purpose, i.e. an increase the productivity of the crops and often remain unused in agroecosystems (Stoicheva et al., 2011). The fertilizers which are not included in the biological cycle of substances are potential a source of negative changes in the solid and liquid phase of the soil (Bordoloi et al., 2013; Wang et al., 2013). The exceedance of nitrogen standards as regards the fertilization application can lead to nitrogen losses, especially in the form of nitrates, which passing through the soil profile (Addiscott, 1996, Alexandrova et al., 2001; Koleva et Stoicheva, 2008; Stoicheva et al., 2003; Smith at al., 2003) are cause pollution of surface and groundwater. It was found that agriculture is a diffuse source of contamination by nitrates and therefore the main priorities of each society should be prevention on pollution and control of "soil-plant-water system" (Oenema et al, 2003; Candela et al., 2008; Stoicheva et al., 1996). In the recent years an increasing attention has been given to groundwater pollution from agricultural sources (Nitrates Directive of the European Union - 91/676/EEC), which accepts and introduces Good agricultural practices in the agriculture. According to the study of many authors (Addiscott, 1996; Mosier, et al., 1998; Oborn et al., 2003; Shroder et al., 2006; Stoicheva et al., 2008) the nitrogen balance can successfully be used as an

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effective tool for assessing the extent of the loss of nitrogen in agricultural ecosystems, as well as, determination the factors increasing the efficiency of fertilizer use and formulation of programs aimed at the its full utilization (Roy et al., 2005; Salo et al., 2006; Stoichev et al., 1998; Koutev et al., 2008; Stoicheva et al., 2011).

The aim of this study is to assess the items of input and output of nitrogen balance in condition of field experiment with vegetable crops.

Material and Methods

The field experiment, subject of this study, is located in South Bulgaria (24^{0}35'E; 42^{0}14'N and 180 m above the sea-level), near the town of Plovdiv, Bulgaria, village Tsalapitsa. During the experimental period 2009-2011 were conducted single-factors fields experiments with various vegetable crops (eggplant, green beans and carrots). The experiment was carried out on Fluvisols, in a vulnerable area in terms of the risk of contamination surface and ground waters by nitrates from agricultural sources. Different N-rates are tested on the background of the phosphorous and pottassium: $T_0(N_0P_{80}K_{80})$, $T_1(N_{80}P_{80}K_{80})$, $T_2(N_{160}P_{80}K_{80})$,kg.ha^{-1}. Soil management practices and other agrotechnical activites are according to the standart technology for the vegetable growing. The arable horizon has the following mean characteristics: light texture, low clay content (18.6%), bulk density between 1.54 and 1.66 g.cm^{-3}, pH_{H2O} = 6.0-6.5, total nitrogen = 0.111%, humus content - 1.23%, and cation exchange capacity – 22.4 cmol.100 g^{-1}. During the studied period have been investigated the chemical composition of every registered precipitation. Depending on the volume of water and the concentrations of chemical elements were calculated their revenue. Periodically were studied for nitrogen content and irrigation waters.

The field plots were equipped with Ebermeir lysimeters (Stoichev, 1974) collecting water from a depth of 50 and 100 cm layers from the surface. Soil characteristics were determined in accordance with the described chemical methods for soil analysis by Page et al. (1982). The pH values and chemical composition (NO_3-N, Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^-, Si) of precipitation, irrigation and lysimetric waters are determined using the following methods: pH – potentiometrically (Arinushkina, 1970); nitrogen content was measured by "Spectroquant Pharo 100"; potassium and sodium were determined by flame photometer, calcium and magnesium – by atomic absorption spectrometry – AAS (Page et al., 1982), hydrocarbonate by titration with $0.02nH_2SO_4$ to pH 4.4 (Arinushkina, 1970).

Results and Discussion

Evaluation of the climate conditions

Of the three experimental years with the most precipitation is 2010, especially on July, when the amount of the precipitation reaches up to 193 mm. Of less precipitation is in 2009 during the vegetation period when the amount of rainfall by months May to August are ranges from 16 to 26 mm. In 2011, their montly distribution is comparatively uniform precipitation but again are not sufficient for the crops during the growing season (Figure 1).

According to the mean diurnal temperature a comparison can be made between 2009 and 2011. The average, mean air temperature is quite similar, as the difference between the two years of months is in the range 1-2^{o}C. During the vegetation period of 2010 there has been some decrease in the mean diurnal temperature which was due to the higher amount of precipitation during these months. The analysis of the maximum air temperature show that during the vegetation period of 2009 extreme temperatures have been observed in July for more than 5-6 days, which is unfavorable for crop development (Figure 2).

In 2010 an increase of the rate of the maximum air temperatures was observed in August, while in other months of the vegetation period the values of this parameter are within the normal range. During the vegetation period of 2011 high maximum air temperatures have been observed since the beginning of vegetation (May), and this trend continued in July and August (Figure 3).

The analysis of the climate data show that meteorological conditions for 2009-2011 are relatively favorable for the growth and development of crops, but for realizing the quality products is necessary on schedule performing of agro-technical measures and and submission of required number of irrigations.

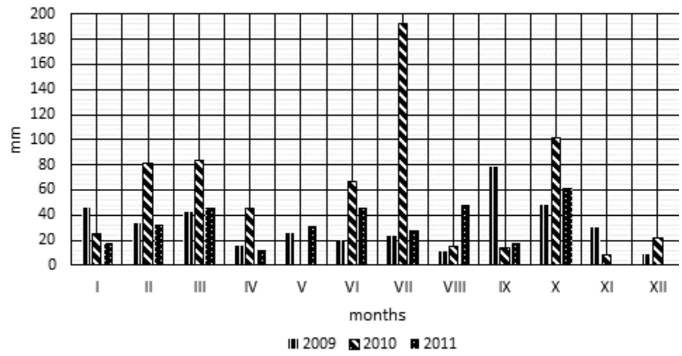

Figure 1. Month's amount of precipitation for the period of 2009-2011years

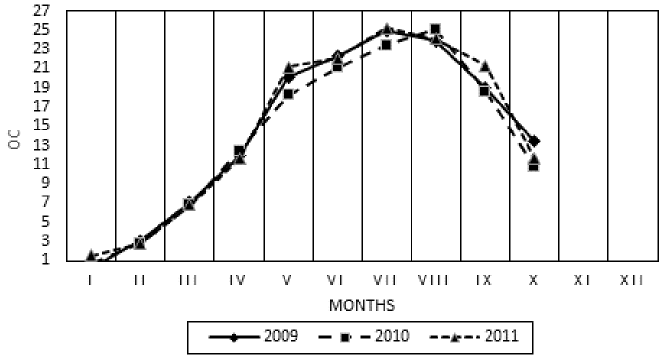

Figure 2. Average temperature of air for the studied years

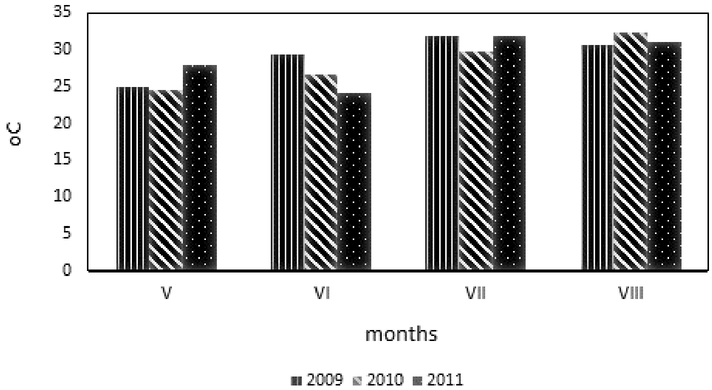

Figure 3. Maximum temperatures of air for the period of vegetation

Content and input of nitrogen with the precipitation

Studies in recent years show that the precipitation and dry atmospheric depositions contain and transfer chemical elements which in most cases have anthropogenic origin and are defined as pollutants with negative impact on the ecosystems in which they are deposited and accumulated (Gauger et al., 2001). Moreover they are significantly item of revenue in the balance of the elements in the agroecosystems. According to the studies of certain authors the seasonal fluctuations in temperature and intensive precipitations are the reason of significant losses of nitrate (Mitchell, 2011). The data presented in the Table 1 show that during the studied period 2009-2011, the content of nitrate nitrogen is from 2,23 to 2,92 mg.l^{-1}, while the total nitrogen in precipitation is in the range of 4,78-6,75 mg.l^{-1}.

Table 1. Average chemical composition of precipitation during the period - 2009-2011

Year	Precipitation, mm	pH	Chemical elements, mg.l^{-1}										
			K^+	Na^+	Ca^{2+}	Mg^{2+}	NH_4-N	NO_3-N	Ntot	HCO_3^-	Cl^-	Si	SO_4^{2-}
2009	384,0	6,60	3,13	1,41	4,25	1,41	3,69	2,95	6,64	31,18	7,61	1,95	31,36
2010	655,0	7,00	2,57	1,48	7,34	0,79	4,43	2,32	6,75	36,02	6,37	0,52	42,11
2011	383,5	6,85	1,72	0,91	5,50	0,50	2,55	2,23	4,78	35,69	7,08	2,11	61,09

The detailed analysis of the data shows a trend of increase of this element in our country especially in recent years.

To assess the impact of atmospheric deposition upon the soil is important to determine the total amount of the ions which included in the annual precipitation. The revenue input of nitrogen in the precipitation is calculated on the basis an average chemical composition and the total annual rainfall (385-655 mm) in the region of Tsalapitsa. Figure 4 show that the average revenue on the most important biogenic element – a nitrogen for years of study varies in the range (18,3-44,2 kg.ha^{-1}).

According to studies of some authors with the increase of nitrogen emissions into the atmosphere during the last years the прихода of nitrogen exceed 30 kg.ha^{-1} as Europe and in world wide (Koleva, 2002).

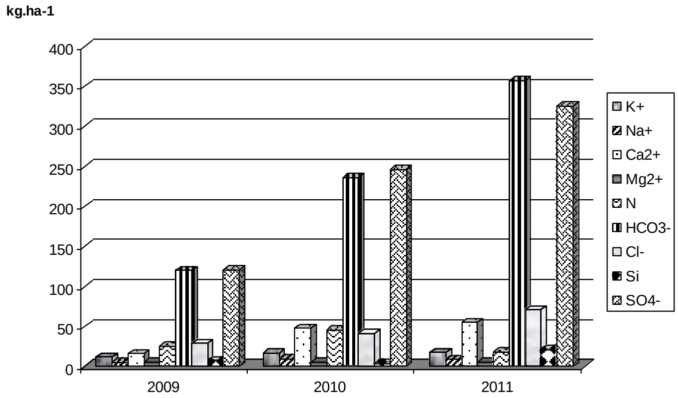

Figure 4. Impact of chemical elements with precipitation (kg.ha^{-1}) for the period, 2009-2011

Contents and input of nitrogen with irrigation water

In this study for irrigation water are used groundwater from wells near the experimental field of Tsalapitsa village. The waters, which used for irrigation of the growing crops, was assessed as a potential source of chemical effects on soils and item of revenue in the biological cycle of substances. It was found that irrigation water increases the natural drainage of the soil, and with it and exports of dissolved nutrients in them and that the excessive irrigation can be the cause of export of nitrogen into the lower soil layers (Wallis et al., 2011). The control of the type, the way and the number of irrigations applied together with the reduction of fertilizer rates are essential to reduce leaching of nitrates (Barros et al. 2012; Poch-Massegú et al., 2014).

The data show (Figure 5) that the average content of nitrogen is in the range (7,77-7,94 mg.l^{-1}). The observed variations in the nitrogen content of irrigation waters (especially the highest values in 2009) are associated with anthropogenic loading the area at intensive cultivation of vegetable crops. It should be noted that the monitoring of the chemical composition of the irrigation waters and a nitrogen revenue with them (of about 18,0 kg.ha^{-1}) is essential at soils of light mechanical composition and anthropogenic loading.

It was found that the values of pH and content of biogenic elements in irrigation waters does not have a negative impact on the soil, but rather they are a significant source of buffering ions (the revenue of Ca^{2+} have values of about 172-229 kg.ha^{-1}).

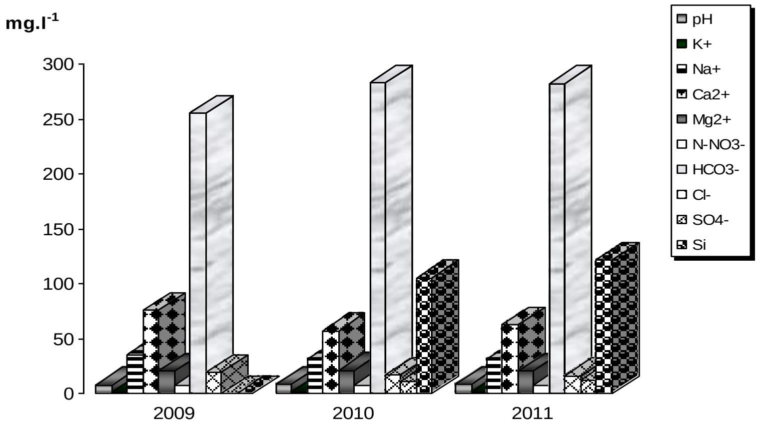

Figure 5. Chemical composition of irrigation water(mg.l^{-1}) during the period, 2009-2011

Content and uptake of nitrogen in vegetable crops growing

The data presented in the Table 2 show that the highest yields were obtained from eggplant from variant T_2. There have been established differences between the variants of fertilization of the order of 2000 kg.ha^{-1} which are statistically unproved. The received yield from the no-treated control is also relatively low in the experimental conditions. It was found that (Table 3) the yield of carrots (root vegetables - fresh mass) ranged between 30570 and 36030 kg.ha^{-1} depending on the rate of fertilizing.

Table 2. Yields (kg.ha-1) of some vegetable crops, 2009-2011

	Yield t.ha-1*		
Treatments	Eggplant, 2009	Carrots, 2011	Treatments
$N_0P_{80}K_{80}$ - T_0	22700	30570	$N_0P_{80}K_{80}$
$N_{80}P_{80}K_{80}$ - T_1	33270	38640	$N_{60}P_{80}K_{80}$
$N_{160}P_{80}K_{80}$ - T_2	36030	38800	$N_{120}P_{80}K_{80}$
LSD ≤ 0,05	1128	1233	
LSD ≤ 0,01	1642	1794	
LSD ≤ 0,001	2467	2697	

*The experience with green beans is destroyed and therefore not accounted yield.

The obtained experimental results showed that increasing the rates of fertilizing insignificantly increases the yield of carrots roots. The highest return on the applied nitrogen fertilization was found in 50% reduction of fertilizer rate calculated by the model as the optimal. The data obtained of earlier our study (Alexandrova et al., 2001) show that fertilization of carrots should be performed after a very good study of soil conditions because the nitrogen fertilizers, especially ammonium nitrate have acidifying effect and carrots are a culture that exhibits an high sensitivity to soil acidity.

Table 3. Absolutely dry biomass and uptake of macroelements with vegetables

Trearments	Absolute. dry biomass kg/ha	Uptake of macroelements, kg.ha-1				
		N	K	Na	Ca	Mg
Eggplant, 2009						
$N_0P_{80}K_{80}$	3660	68,2	148,5	1,1	90,9	12,1
$N_{80}P_{80}K_{80}$	4890	121,8	207,9	1,5	116,9	16,1
$N_{160}P_{80}K_{80}$	5070	148,6	240,8	2,0	108,5	16,7
Carrots, 2011						
$N_0P_{60}K_{60}$	4000	44,9	130,8	22,4	4,16	9,1
$N_{60}P_{60}K_{60}$	5580	101,1	238,2	25,9	5,96	16,0
$N_{120}P_{60}K_{60}$	5970	112,4	248,7	21,7	6,98	17,0

The total biomass on eggplants range from 3660 to 5070 kg.ha-1. The uptake of nitrogen with the agricultural part of the production from eggplant under no fertilization with nitrogen control is 68,2 kg.ha-1 while the maximum fertilization variant reaches to148,6 kg.ha-1 (Table 3). It should be noted that when increasing the fertilizer rate (N_{160}) the uptake is lower than the amount of nitrogen imported input.The similar results were observed in our early investigations (Alexandrova et al., 2007, Mitova et al., 2011). Therefore will create a real danger of residual nitrate nitrogen accumulation in the soil which is moving into deeper soil layers. In the carrots (Table 3) the total biomass ranges from 4000 to 5970 kg.ha-1, and the amount of nitrogen uptake is ranged from 44,9 to 112,4 kg.ha-1. From these results it follows that compensation of input with the fertilizers and the output amounts of nitrogen with biomass was observed in T_2 variants.

Content and nitrogen losses in lysimetric water

It was established that the quantities of drainage water under layers 0-50 and 0-100 cm at growing of vegetables for the study period 2009-2011 varied considerably. The results show that the highest amounts of drainage waters were recorded in 2011 when growing carrots - 70,51 l.m2 for the layer 0-50 cm and lowest of 1,92 l.m2 for layer 0 -100 cm when growing eggplant.

The nitrogen losses from agricultural areas depend on the amount of drainage waters and according to some authors varied in a quite widely from 8 to 45 kg N ha-1. It was established good strong correlation between the migration of nitrogen in the soil profile and the waters capacity of the soil (Beaudoin et al., 2005, Stoicheva, 2011). Data analysis shows that the exported quantities of nitrogen from the control (fallow) at growing vegetable crops in the study period 2009-2011, were lower compared to the fertilization variants and are depending on the volume of filtrate and the it contents in the lysimeter waters.

The greatest of nitrogen losses have been established in growing carrots at 2011 where exports of N reaches 8,3 kg.ha-1 for the layer 0-50 cm (unpublished data). In the variant with a maximum rate of nitrogen fertilization through 2009 the pH values of the water is lower in comparison with the control. It was found increased water migration of nitrogen and calcium and less pronounced such as in magnesium and sodium. The output of potassium which contents is not affected by fertilizing rate are quite lower.

Table 4. Averidge chemical content and uptake of chemichal elements with lysimetric water at growing of eggplant, 2009-2011 years

Variant	Depth	pH	K^+	Na^+	Ca^{2+}	Mg^{2+}	$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	HCO_3^-	Cl^-
			Content of chemical elements, mg.l-1							
Fallow	0-50	8,25	2,61	15,60	80,50	18,75	1,16	0,93	260,33	16,53
T_2	0-100	7,20	3,72	24,12	33,12	12,75	1,51	3,61	56,84	22,52
			Uptake of chemical elements, kg.ha-1							
Fallow	0-50	8,25	0,03	0,20	1,00	0,20	0,01	0,01	3,30	0,20
T_2	0-100	7,20	0,07	0,50	0,60	0,20	0,03	0,07	1,10	0,40

The nitrogen balance in vegetable crops growing

The establish of equilibrium in agroecosystems as a whole requires a long period of time for which are typical relatively constant conditions for management of the system and revenue of the elements are approximately compensated by respective losses. Therefore, to achieve the steady state of agroecosystems under vegetable cultivation is necessary assessment of imported chemical elements and reporting of export from agricultural ecosystems, including and the potential losses of nitrogen. For this purpose, it is essential to make a conditional nitrogen balance, by quantifying the input and output items. In Table 5 is presented of conditional nitrogen balance in 2009 and 2011, when in the frame of long-term field experiment with vegetable crops are grown eggplant and carrots. In the nitrogen balance in this field experiment are included: inputs with precipitation, fertilizers and irrigation water, exports of biomass the growing crops. Not reported of losses with lysimetric waters, as they are insignificant.

Table 5. Conditional balance of nitrogen in the vegetable growing

Variant	Input with precipitation	Input fertilizers	Input with irrigation waters	Total input	Output with plants	Total uptake	Balance
			Eggplant, 2009				
N0	25,5	0	18	+43,5	68,2	- 68,2	-24,7
N80	25,5	80	18	+123,5	121,8	-121,8	+1,7
N160	25,5	160	18	+203,5	148,6	-148,6	+54,8
			Carrots, 2011				
N0	18,3	0	18	+36,3	44,9	-44,9	-8,6
N60	18,3	60	18	+96,3	101,1	-101,1	-4,8
N120	18,3	120	18	+156,3	112,4	-112,4	+43,9

From the analysis of the results obtained for nitrogen balance was showed that near the equilibrium state are variants of the fertilization - T_0 and T_1 in the both cultures. The conditions under which nitrogen balance reaches lows positive (T_1 - eggplant) or negative (T_1 - carrots) values are retained for a long period of time is defined as sustainable equilibrium, ie create of conditions for sustainable development of crop. As a taking into account the input and output of the nitrogen in these two cultures at variants T_2 (N_{160}) there is a positive balance in eggplant +54,8 kg.ha^{-1} and carrots +43,9 kg.ha^{-1}. It should be noted that in calculating the conditional of nitrogen balance to input items added input to precipitation (18,3-25,5 kg.ha^{-1}) and irrigation water (18 kg.ha-1) what makes a sensitive amount of 36,0 – 43,5 kg.ha^{-1}. It should be underlined that if this income is not reported will not be identified an excess nitrogen in T_2 variants after harvesting eggplant and carrots.

This fact is very important and should be taken into account in future research in order to achieve a sustainable balance within the research agroecosystems in which induced anthropogenic load changes will not have a negative character.

Conclusion

The results show that the input the range over 40 - 50 kg.ha^{-1} nitrogen with precipitation and irrigation waters as a source of loading of agroecosystems is essential and affects nitrogen balance under conditions of intensive agriculture. The export of nitrogen with vegetable crops growing is moving within 68-148 kg.ha-1 for eggplant and 45-110 kg.ha^{-1} for carrots, which is relatively low compared with optimum exports of this element with such intensive vegetable crops. It should be noted that during the study period the amount of drainage in the experience of vegetable crops is insignificant, so that losses of nitrate nitrogen in the drainage runoff are very low in quantity and are not included in the calculation of nitrogen balance.

In conclusion should be noted that in vegetable cultivation in areas with environmental restrictions (especially on alluvial - meadow soils) it is necessary to take into account the input of the chemical elements with the precipitation and irrigation waters. Should be make recommendations for environmental norms of nitrogen fertilization for to realize the maximum the incorporation of nitrogen in the biological cycle of substances, which is essential for the protection of different environment components of environment.

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