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METHODOLOGICAL APPROACHES FOR ASSESSING THE DRIP IRRIGATION IMPACT ON THE PEDO-ECOLOGICAL STATE OF IRRIGATED SOILS

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Abstract

The paper presents modern approaches to monitoring and assessing the pedological-ecological state of soils under drip irrigation conditions, which includes the features of soil samples selection taking into account the area of the irrigation pipeline and non-irrigated aisles (rows), laboratory-analytical studies of soil samples, calculation of the quantitative characteristics of variation integral indicator of the investigated factors, establishment of a the representative profile / well. Impact assessment of drip irrigation method on the soil processes and the agro- ameliorative state of irrigated lands was carried out according to the soil indicators of the profiles / wells, representative for the studied zones in the rows and the aisle. Proposed approaches allow a reliable assessment of drip irrigation intensity influence on soil processes in order to maintain the pedological-ecological, agro-ameliorative state of the irrigated soils at the safe level, preserve and increase the soil fertility.

Key words: *drip irrigation, pedological-ecological state, soil properties, representative profile/well.*

INTRODUCTION

Irrigation is the most powerful factor of human intervention in the natural-ecological environment and a strong factor in soil transformation. Economically and ecologically, drip irrigation technologies are now considered the most productive in agriculture sector. The annual area of irrigated land already reaches 65 - 75 thousand hectares (Шатковський, 2016; Цуркан, 2015). An important feature of land drip irrigation is the introduction of dissolved fertilizers and microelements with irrigation water (fertigation), growth regulators and plant protection products (herbigation, insecticide, fungi, etc.).
With drip irrigation, which is characterized by the local conditions of soil humidity, a rather nature complex of the moisture with salts and nutrients movement dissolved in it, is formed (Lubana & Narda, 2001; Ромащенко, 1998; Чорноземи (2016); Цуркан, 2015, 2018). These processes leads to the manifestation of local agrogenic differentiation of soil properties due to uneven distribution of soil moisture (Рекомендації, 2012), formation of increased concentration of nutrients (Tsurkan et al., 2018; Шатковський, 2007), changes in the soil salt regime in the places with irrigation water localization (Цуркан, 2018; Ромащенко, 2014), changes in the microbiological soil activity (Венера & Красимов, 2002) and in the agricultural land history use and other factors.
The increased content of nutrients in the fertilizer localization zone persists for a long time and, as a rule, is not limited to one growing season. Therefore, it is difficult to choose a place (area) with the representative soil profile, to obtain objective and correct data for assessing the impact of agricultural activities on the pedological-ecological state of lands under the drip irrigation conditions.
There is a known method of sampling soil under drip irrigation conditions (Балюк et al., 2009), which provides for sampling soil in the area of the irrigation pipeline, crops rows area, on the border of the humidification circuit and in non-irrigated aisles (area). Conducting the analysis of such areas allows one to determine the pedo-ecological soil state in drip irrigation

conditions and predict the yield of agricultural crops.
To study the microdistribution of mineral nutrients from the fertilization lands, the authors (Трапезников et al., 1999) proposed the method including layer-by-layer of soil sampling, in form of horizontal monoliths with size 2 × 2 cm, on perpendicular to the direction of the fertilizer application.
Determination of the optimal points of soil sampling for operational control of the processes of drip irrigation and fertigation, the method was proposed for sampling soil for moisture (by setting tensiometers) and mineral nutrients content at the points of maximum concentration of the root system in the middle of the distance between the irrigation pipeline and the border of the moisture zone in the plant budding phase at depth of 20 cm, and then at 40 cm (Лимар & Кащеєв, 2011; Tsurkan et al., 2018, 2019).
Under the conditions of local application of liquid and gaseous nitrogen fertilizers, was proposed to evaluate the change in the parameters of soil fertility indicators by taking soil samples, avoiding the formation of parallel or perpendicular lines that coincide with the place of fertilization (tape) and equal distances between spot samples. Thus, 20 individual soil samples are taken from an elementary site from a depth of 20 cm, which are thoroughly mixed under laboratory conditions and a mixed average soil sample is formed (Мирошниченко et al., 2016).
The generally accepted methods of pedoagro-chemical survey and assessment of the irrigated lands state do not allow for an objective assessment of soil fertility indicators in cases of local application of fertilizers due to an increase in the spatial variability of many of them, which increases the likelihood of taking an insufficiently representative sample and affects the reliability of the research results.
Consequently, studies should refer to a specific profile or well, which would be representative (typical) for this study object. Typically, the representative profile ($P_{typ.}$) is considered to be the profile or well, which the values of the studied factors deviate least from the average group of these factors. Moreover, as a rule, the effective factors are compared. To identify the changes that occur in the soil under the drip irrigation influence, comprehensive studies are carried out, then the selected profile should be average or representative (typical) not for one indicator, but for a set of various indicators of the soil.
Thus, the optimal way to assessing the impact of drip irrigation on the pedological and ecological properties of soils is to establish representative profiles / wells for irrigated and non-irrigated (space between rows) zones according to factorial characteristics. To do this, it is necessary to taking into account the close relationship of the factors-arguments with the effective indicator, identifying the quantitative influence of the factors-arguments on the effective indicator, according to the ecological indicators of which the impact on soil processes of the drip irrigation method is assessed. In this regard, the purpose of our research is to develop modern approaches to monitoring the state of the soil cover under the drip irrigation conditions.

MATERIALS AND METHODS

The research was carried out on the experimental fields of "Dobra Gorodina", Belyaevsky district, Odessa region. The field experiment was laid on the southern chernozem, low-humiferous, clayey-loamy in conditions of drip irrigation and vegetable crops rotation. The farm has been using a drip irrigation system for watering vegetable crops since 1996-1997. Alternation of vegetable in crop rotation: tomatoes - sweet peppers - onions (2 years) - spring barley (2 years).
For irrigation, the water from Dniester River was used. Irrigation water is characterized by the following properties: hydrocarbonate - calcium composition, fresh (mineralization <0.5 g/dm^3), pH_{H2O} = 7.5-7.8, concentration of toxic ions - 4 mmol·eq/dm^3. According to agronomic indicators, the irrigation water belongs to the I quality class, and it is suitable for irrigation without restrictions. In order to optimize the nutritional regime with irrigation water (in the vast irrigations majority), dissolved fertilizers and microelements are applied. Mineral fertilizers are represented by phosphorus, nitrogen, potash - both simple and complex. The pre-irrigation soil moisture is maintained at the level of 80-85 - 70% of the

lowest water-holding capacity after the phases of plant development.

Taking into account the local natural conditions of soil moisture with drip irrigation, soil samples were taken in the area of the irrigation pipeline and in the middle of the non-irrigated zone (row spacing). Soil samples were taken to a depth of 1 m, in layers of 0-10, 10-30, 30-50, 50-70, 70-100 cm. Sampling from the 0-10 cm soil layer is due to the technology of growing seedlings, in which irrigation pipelines are laid into furrows to a depth of 10 cm.

In the work field process, the laboratory and analytical studies of soil samples were carried out according to standard certified methods, followed by statistical processing, which included the determination of the salt composition of the water extract, the physico-chemical properties of soils, the content of humus, mineral nitrogen, mobile phosphorus and exchangeable potassium by the Machigin method.

The analyzes were carried out with STATISTICA 7.0 (StatSoft Inc., USA). Graphs and diagrams were built using MS Excel 2010 (Microsoft Corp., USA) and STATISTICA 7.0 (StatSoft Inc., USA).

RESULTS AND DISCUSSIONS

As a result of pedological and agrochemical examination of chernozems under drip irrigation conditions, during the soil samples selection in the area of the irrigation pipeline and in the middle of the non-irrigated zone (row spacing), it was found that statistically processed indicators of the most important agricultural production characteristics of the soil differed significantly in the upper layer of 0-50 cm. Within the experimental plot and along the soil profile (in deep), the parameters of the content of chlorides, sulfates, sodium, nitrate and ammonia nitrogen, mobile phosphorus, carbonates had a high coefficient of variation (V > 25%).

The calculated variation coefficients for above parameters were characterized by the high variability both in the rows and in the aisles. That is, the use of drip irrigation causes a significant increase in the heterogeneity of soil properties within the field and in deep of the profile, which leads to a variety of properties and their agro-ameliorative state.

As our research has shown, the residual effect of previous years of soil moisture and fertilization when growing vegetable crops, affects the state of sowing spring barley (a catch crop in a drip-irrigated vegetable crop rotation). The diversity of sowing barley is manifested in a higher plant height, and especially in a better formed ear in the place of the former rows.

Based on the studies carried out, we believe that in order to assess the ecological impact of drip irrigation on the soil properties of irrigated soils, it is necessary to establish profiles / wells representative for the zones of the irrigation pipeline and the non-irrigated zone (row spacing), which will increase its reliability and objectivity.

Proceeding from the fact, that changes in humus content are not only directly related to changes in all soil properties, but also clearly reflect the influence of external processes, we have taken the humus content (*y*) as an effective factor. Humus is an integrating indicator that determines most of the properties of soils and their overall fertility (Baliuk et al., 2020). At the same time, it reacts rather quickly to external influences of a natural and, mainly, anthropogenic nature, being a reliable indicator of changes occurring in the soils. Soil indicators were taken as factors-arguments (x_i = 1, 2, 3, …11) are presented in Table 1.

Thus, the correlation task with 11 factorial features was compiled. The coefficient of multiple determination R^2 turned out to be 0.96 for irrigation pipeline zone, and 0.99 for the non-irrigated zone, that is, the specific weight of the combined effect of the selected factors on the humus content is 96% and 99%, respectively.

The number of population units for the test line under the irrigation pipeline and non-irrigated area: $j = 40$ ($p = 8$ wells, in each of which soil samples were taken from the depths ($k = 5$): 1 - 0-10 cm; 2 - 10-30 cm; 3 - 30-50 cm; 4 - 50-70 cm; 5 - 70-100 cm.

The deviation from the ratio unit of the quantitative value of each factor x_i (i = 1, 2, 3, ...11) to its average value for the entire number of aggregate units (j = 1, 2, 3, …40) was determinate (1):

$$\delta_{ij} = \left|1 - \frac{x_{ij}}{\overline{x_i}}\right|,$$ (1), where: x_{ij} – the factor value i in j - in the sampling soil;

$\overline{x_i}$ – the average value of the factor i for the set of soil samples.

Table 1. Results of establishing a representative soil profile/well by a set of factor signs

Factor name	Symbols	Testing line - under the irrigation pipeline		Testing line - in the middle of the non-irrigated area (row spacing)	
		r_{yx_i}	d_{yx_i}	r_{yx_i}	d_{yx_i}
Humus, %	У	-	-	-	-
pH_{H2O}	X_1	-0.653	0.426	-0.685	0.469
HCO_3^-, mmol per 100 g of soil	X_2	0.237	0.056	0.081	0.007
Cl^-, mmol per 100 g of soil	X_3	0.111	0.012	0.039	0.002
SO_4^-, mmol per 100 g of soil	X_4	-0.541	0.293	-0.527	0.278
Ca^{2+}, mmol per 100 g of soil	X_5	-0,250	0,063	-0,415	0,172
Mg^{2+}, mmol per 100 g of soil	X_6	-0,037	0,001	-0,457	0,209
Na^+, mmol per 100 g of soil	X_7	0.855	0.732	0.814	0.662
K^+, mmol per 100 g of soil	X_8	-0.909	0.826	-0.900	0.810
Mineral nitrogen, g per 100 g of soil	X_9	0.575	0.331	0.418	0.174
Mobile phosphorus, g per100 g of soil	X_{10}	0.847	0.718	0.837	0.700
Exchangeable potassium, g per 100 g of soil	X_{11}	0.951	0.904	0.957	0.915
Multiple determination coefficient	R^2	-	0.960	-	0.990
Correlation ratio	R	0.980	-	0.970	-

The individual indicator of quantitative characteristics variation of the study factors, which characterizes the sum of linear deviations for all soil sampling (j = 1, 2, 3, ... 40) distributed on p groups of wells (1, 2, 3 ... 8) and k subgroups of sampling depths (1, 2, 3 ... 5) was determined (2).

$$v_{pkj} = \sum_{i=1}^{n} \delta_{ij} d_i$$ (2), where:

δ_{ij} – deviation from the ratio unit of the quantitative value of the factors x_{ij} to its average value $\overline{x_i}$, taken in modulus; d_i – partial coefficient of determination i-factor.

The integral criterion for establishing the typical (representative) well as the sum of individual indicators of the quantitative characteristics variation of the study factors by the depths of extraction for each well was calculated.

The quantitative value of the integral criterion for establishing the type profile / well of which will be minimal, is the typical (representative) for the irrigation pipeline zone and non-irrigated zones. So, in our example, the criterion minimum value for setting the typical profile / well according to the research results is observed for irrigation pipeline zone along the well p_2, and for the of non-irrigated row spacing zone - p_{10} (Table 2).

Thus, the $P_{typ.}$ for the irrigation pipeline area there is p_2, and for non-irrigated row spacing area - p_{10}. Soil indicators of these wells have the smallest deviation from the average group value in terms of a set of factor signs, that is, they are representative of the studied zones. In addition, the individual values of the criterion for the sampling depth do not exceed the average values for the corresponding sampling depth which makes it possible to take into account the distribution of indicators along the soil profile (Table 2).

Table 2. Calculated values of individual indicators of studied factors quantitative characteristics and an integral criterion for determining the typical soil profile/well

No. of subgroup depths Soil sampling / No. of profiles / wells group	k_1	k_2	k_3	k_4	k_5	$\sum_{k=1}^{5} \nu_{pkj}$
	$\nu_{pkj} = \sum_{i=1}^{n} \delta_{ij} d_i$					
Sampling line - under the irrigation pipeline						
p_1	1.26	1.10	1.26	1.01	0.95	5.58
p_2	**0.76**	**0.87**	**0.81**	**0.87**	**0.93**	**4. 30**
p_3	0.85	0.91	0.96	0.90	0.93	4.56
p_4	1.12	1.13	0.95	1.00	0.94	5.13
p_5	1.02	1.00	0.96	0.87	0.90	4.75
p_6	1.25	1.05	0.82	0.91	0.91	4.94
p_7	0.91	1.14	0.89	0.93	0.91	4.77
p_8	1.01	0.82	0.89	0.87	0.83	4.42
$\overline{\nu_{kj}}$	*1.02*	*1.00*	*0.94*	*0.92*	*0.91*	-
Sampling line - in the middle of the non-irrigated area (row spacing)						
p_9	1.13	1.56	0.99	0.98	1.01	5.67
p_{10}	**0.91**	**0.96**	**0.99**	**0.94**	**0.94**	**4.74**
p_{11}	0.99	1.18	0.91	0.99	0.99	5.06
p_{12}	1.10	1.43	0.98	0.95	0.90	5.35
p_{13}	0.85	1.40	0.97	0.94	0.90	5.06
p_{14}	1.01	1.22	0.92	0.98	0.94	5.07
p_{15}	1.11	1.49	0.97	0.97	1.00	5.53
p_{16}	1.17	1.44	1.01	1.01	1.05	5.68
$\overline{\nu_{kj}}$	1.03	1.33	0.97	0.97	0.96	-

The method to assess the impact of the drip irrigation and the agro-ameliorative state of irrigated lands under drip irrigation conditions on soil processes need to carry out using the soil indicators of representative profiles / wells for the studied representative zones.

Along with the deviation of each factor from its average group value, the proposed criterion takes into account the qualitative and quantitative dependence of the factors-arguments and the effective signs. The proposed criterion for establishing the representative profile / well takes into account the deviation of the factor-arguments from their average values, taking into account the tightness of each relationship of the factor attributes - x_i with the effective attribute - y.

Assessment of the drip irrigation impact on soil processes and the agro-ameliorative state of irrigated lands under drip irrigation conditions along representative profiles/wells for irrigation pipeline zones and non-irrigated row spacing allows obtaining more information on the land and soil regimes, processes, properties and dynamics of their changes. The proposed approaches make it possible to reliably assess the intensity of drip irrigation influence on soil processes in order to maintain the ecological and agro-ameliorative state of irrigated soils at a safe level, preserve and increase their fertility.

CONCLUSIONS

In drip irrigation conditions for objective and correctly assessment of its influence on the soil processes and the agro-ameliorative soils state, the soil sampling zone is of no small importance. Therefore, when conducting an agro-ameliorative survey of soils under drip irrigation conditions, it is recommended to take soil samples separately, in the irrigation pipeline zone and in the middle of the non-irrigated zone (row spacing).

Given the high variability both in the rows and in the row-spacing of statistically processed indicators of the most important agro-production characteristics, it is mandatory to establish profiles/wells representative for the irrigation pipeline and the non-irrigated (row spacing) zones. The drip irrigation impact on the pedological-ecological state is assessed by soil indicators of profiles/wells representative for the studied zones.

Thus, the proposed approach is more objective, mathematically reliable, since the influence of the drip irrigation method and the agro-ameliorative state of irrigated lands are assessed by pedo-ecological indicators of representative profiles/wells for the irrigation pipeline and the non-irrigated zones. Consequently, conducting pedo-ecological monitoring of the soils state in drip irrigation conditions and evaluating its effect according to the proposed method is suitable for all agricultural crops, without exception, and any schemes for using drip irrigation.

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