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USE OF FERTIGATION SYSTEMS FOR ENVIRONMENTAL SAFETY OF *Solanaceae* SPECIES UNDER PROTECTED SPACES

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Abstract

The degradation of agricultural ecosystems began with the application of intensive agriculture, which cannot be separated from the problems related to it. In this context, it is more important than ever to dismiss any polluting technology, in order to defend the healthy agriculture concept and to model life based on the existing natural cycles. The aim of study was to achieve an equally balanced eco-system, based on self-regulation instead of major human intervention. To achieve this goal, at the University of Agricultural Sciences and Veterinary Medicine in Iasi it was organized an experiment in randomized blocks, with three repetitions on two species in tunnels, using different methods of irrigation and fertilization with average impact. The results obtained highlight that fertigation leads to sustainable yields because of the controllable application of water and nutrients, with direct long term positive implications in reducing soil compaction and salinization. The use of microorganisms-based fertilizers leads to significantly increased yields and, on the long term, enrich soil composition.

Key words: fertilization, horticulture, irrigation, sustainable system, unpolluted soil

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1. Introduction

Providing water became, on a global scale, a more and more debated and delicate subject. According to World Population Statistics (WPS, 2021) world population increases with 80 million persons every year; accordingly, the yearly water consumption will increase to 64 billion cubic meters. The long-term foresight assumes that the major global competition will be for water (World Water Assessment Programme, 2012).

In Romania, approximately 12 million hectares of agricultural land (of which 80% arable land) are affected by one or several limitations: frequent drought (7.100.000 ha), periodical water excess (3.781.000 ha), hydraulic soil erosion (6.300.000 ha), landslides (702.000 ha), wind erosion (378.000 ha), salty and alkaline soils (614.000 ha), strong and moderate acidity (3.424.000 ha), low and very low humus content (7.485.000 ha), low and very low content of accessible phosphorus (6.330.000 ha), low nitrogen content (5.110.000 ha), low content of accessible potassium (787.000 ha), zinc deficiency (1.500.000 ha), chemical pollution (900.000 ha), pollution with oil and salt water (50.000 ha), degradation due to different public work (30.000 ha), occupancy with different solid residues 25.000 ha (ICPA, 2009).

The development of agriculture led to the intensive use of irrigation, combined with the long-term use of fertilizers, thus generating pollution due to the increased level of nutrients in the underground and surface waters. Irrigation is as an important technological measure, leading to the increase of vegetables yield, and is not dependant on the quantity of precipitations, because irrigation compensates the

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water deficiency according to the requirements of the crop (Caruso et al., 2018).

Vegetables need an amount of water 10.000 times higher than the amount of minerals they absorb from within the soil (Ispas et al., 2020). The amount of water consumed depends on the species, because of different production of the dry matter achieved per unit area and the transpiration coefficient (Hoban et al., 2007). An accurate determination of crop water requirements is important to perform an optimal irrigation schedule and increase crop yields, water use efficiency and farm profits, while reducing costs and energy use, preventing surface and groundwater pollution. The evaporation of soil water increases the water requirements of vegetable crops; high temperatures, soil compaction and lack of vegetation increase the evaporation. Irrigation can provide these high amounts of water; irrigation is frequently achieved through open channels, but the efficiency of this method is reduced. Studies have found a lower rate of evaporation (E) compared to transpiration (T) after the use of drip irrigation practice, which indicates that drip irrigation can reduce evaporation significantly. Soil moisture decreases greatly in both shallow and deep layers (Mirás-Avalos et al., 2020; Wang et al., 2020). Drip irrigation, performed with pressurized systems, has a significant higher efficiency. This method (also known as micro-irrigation) implies the slow and constant delivery of small amounts of water through drip emitters or small orifices along polyethylene pipes or bands. Drip irrigation systems operate with lower volumes and require lower pressures than the traditional ones (Savva and Frenken, 2002).

In the overall context regarding the influence of natural and technological conditions over soil, we may refer to a triad, but not without consequences: soil-water-fertilizers. The requirements of irrigation water are strongly connected with the tolerance of crops to water mineralization, taking into account that an unsuitable water may lead to soil salinization (Doneen, 1999).

Williams (2001) noticed that salinization is a global environmental phenomenon, affecting different aspects of life, changing the chemical composition of natural water resources, degrading the quality of water supply, contribution to loss of biodiversity, loss of fertile soil, collapse of agricultural, changing of local climatic conditions, and creating major health problems.

Salinity affects crop yield all over the world; 20% of cultivated land and 33% of irrigated land, are salt-affected and degraded, soil salinization reducing the amount of water available for the crops (Machado and Serralheiro, 2017; Paudel et al., 2020). The formation of salinized soils is due to natural causes (natural alteration of the solid fossil salts), but also to the poor water management, caused by human activity.

Salinized soils (and especially those with low depth underwater and in severe drought conditions) are not suitable for the administration of chemical amendments, soil conditioners or fertilizers (Grumeza and Klepș, 2005). In Romania, salt accumulation is caused by the climate, with a dry season during summer, associated with hollow grounds and insufficient drainage of the low depth underground waters (Stan and Stan, 2010).

Because vegetable crops have a superficial root system, they need high amounts of water; in greenhouses and solariums, where water from precipitations in only partially harnessed, this is a limiting fact (Popescu, 2004). Water demand may reach 1500 m^3/ha, in critical periods (Indrea and Ciofu, 1992; Pelaghia, 2004). Tomato crops, for example, are growing when the water content of soil is lower than 70-80% of the field water capacity, imposing 7-8 irrigations during the vegetation period, with amounts reaching 300-400 m^3/ha (Apahidean and Apahidean, 2000).

Tomato crop is very suitable for fertigation in open field and greenhouses, as it has a high production efficiency, a high content of dry substance and improved quality parameters (size, firmness, soluble sugars) when compared with conventional irrigated and fertilized crops (Alcantar et al., 1999).

Pan et al. (1999) have compared the methods and noted that fertigation led to a production of 72 t/ha, while conventional irrigated and fertilized crops achieved only 44 t/ha. In the same vein, fertigation doubled the amount of available nutrients, being considered one of the most important factors for yield increase. There is no free water on the crops when using drip fertigation and thus the burning of crops is avoided when temperature rises over 40ºC.

Fertilization is another important measure in order to avoid the damage of land wealth on long term and to transform the crops in a source of diseases. In glasshouses and greenhouses, the consumption of mineral substances of the crops is very high and fertilization should be based on agrochemical charts, in order to avoid the formation of salts, the lack of balance between *nutrients* and in order to provide the optimum levels of the fertilizing elements (Stan and Stan, 2010).

Supplementary fertilization is needed in greenhouses, besides the base fertilization, in order to obtain higher yields. The amounts of fertilizers used in greenhouses are 5-10 times higher than the ones for field crops; the N: P: K ratio is also affected (Stan and Stan, 2010; Stoleru et al., 2014). Under these circumstances, the residues of harmful chemical elements in soil becomes a real problem.

Diacono and Montemurro (2010) concluded that regular addition of organic amendments increases the soil physical fertility, mainly by improving aggregate stability and decreasing soil bulk density and addition of exogenous organic matter to cropland can lead to an improvement in soil biological functions, even more than 15 years after spreading.

The aim of the study was to evaluate different fertilization methods (both classic and alternative) in order to establish the variant which has the potential to keep a balanced ecosystem, while improving crop yield, with emphasis on the fertilization with microorganisms-based products; the effect over two crops was assessed: tomato and pepper crop.

2. Material and methods

2.1. Experimental setup

A fertigation system was designed and tested within the Machinery Department of the University of Agricultural Sciences and Veterinary Medicine from Iasi. The system is aimed to provide the necessary nutrients to vegetable crops grown in protected spaces by delivering the fertilizer simultaneously with the irrigation water. The experiments were carried out at the horticultural farm belonging to the university's research station.

The experiments were performed over a *Minaret* F1 tomato crop *(Lycopersicon esculentum* Mill.) and a *Brillant F1* pepper crop (*Capsicum annuum* L.) belonging to the *Solanaceae* family, organized in six versions (Table 1). The specific growing technology was used for each crop (Corduneanu et al.; 2015, Corduneanu et al.2016).

The experiments were carried out in a semi-circular greenhouse of 135 m^2, with the width of 5.4 m and the length of 25 m (Fig. 1). The plants were grouped in five experimental variants, in strips distanced at 80 cm; on a strip, there was a 60 cm distance between the rows, while the distance between the plants on a row was 45 cm, with a density of 31740 plants/ha.

Fertilization is aimed to provide the necessary nutrients during the entire vegetation period (Hoza, 2011). In this experiment there were three types of fertilizations for each experimental variant: fertilization at the same time with the drip irrigation, classic fertilization and fertilization with microorganisms-based products. For the experimental variant in which fertigation was applied, the nutrition was performed twice a week, in the morning. The fertilizers were represented by the Nutrispore® - NPK (MgO) 30-10-10, Nutrispore® NPK (MgO) 15-10-30 and Nutrispore® NPK 12-48-8. The amount of fertilizer per plant was 2g/ application. In order to achieve a well fertigation, plant nutrition was performed between two water applications. Fertigation was performed using a specially designed system (Fig. 2) composed of a fertilizer tank, an automatic programming unit and the water distribution network (Corduneanu et al., 2015).

Fig. 1. Semi-circular tunnel type greenhouse (original photo)

Fertigation was performed as follows: in the first stage the valve (7) was open for ten minutes, in order to fill the dripping lines (13) with water; in the meantime, the fertilizer tank (1) was filled with 30 litres of water. The fertilizing solution was prepared separately, by mixing the hydro soluble fertilizer with water, and was then introduced into the fertilizer tank and was mixed with the water by the stirrer (2). The fertilizer tank valve was opened and the programming unit was turned on; thus, the fertilizing solution was incorporated into the irrigation water through the ejector (10).

Fig. 3 presents a view of the fertigation system (Corduneanu et al., 2015, 2016). Water was supplied to the greenhouse through the water line (1), by opening the valve (2). The amount of water is registered with the water flowmeter (3). Once the valve (4) is opened, the fertilizing solution coming through the hose (5) is introduced into the irrigation water. The irrigation water is then directed to the water distribution pipeline (6) and from here to the dripping tapes (7), which have dripping devices for each plant (8) (Corduneanu et al., 2015; Corduneanu et al., 2016). After the fertigation was ended, drip irrigation has continued for ten minutes in order to completely evacuate the fertilizer solution from the system.

For the classic fertilization method, the fertilizers were spread in the area of each plant; the following fertilizers were used: Cristaland® NPK 20-20-20 for base fertilization; Cristaland® NP 15-50 + 2MgO in the phase of first inflorescence; Cristaland® NPK 9-18-27+ 2 MgO when the first fruits were formed.

Table 1. Experimental design for tomato and pepper crops

Experimental variant	***Fertilization method***	***Irrigation method***
V_1	Through the irrigation water	Drip
V_2	Classic- spreading (solid fertilizer+drip irrigation)	
V_3	Classic- spreading (fertilizer based on microorganisms +drip irrigation)	
V_4	not fertilized	
V_5	not fertilized	Ditch

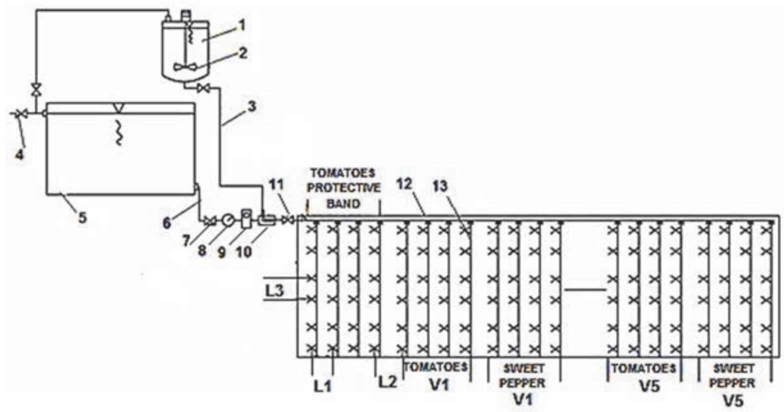

Fig. 2. Simplified schematic of the drip irrigation system: 1- fertilizer tank; 2- stirrer; 3- fertilizing solution feeding pipe; 4 - connection for the buffer tank water supply; 5 – irrigation water tank; 6 - irrigation water supply pipe; 7:11 - valves; 8 – water flowmeter; 9 - programmer; 10 - ejector for mixing the water-fertilizer solution; 12 - main pipe; 13 - dripping pipeline; L1 - spacing between rows on tape; L2 - distance between tapes; L3 - distance between plants in a row

The microorganisms-based fertilizer was Micoseed® MB; it was spread in the area of each plant -3 days before planting. According to literature data, Micoseed® MB is based on *Glomus sp*., *Beauveria sp., Metarhizium sp. and Trichoderma sp*. (Stoleru et al., 2012; 2014). For the same experimental variant two fertilization treatments with Nutryaction® were applied in order to enhance the biological activity of the plants. In V4 version the plants were not fertilized; this was the control sample for drip irrigation. Variant V5 was the control sample for ditch irrigation and no fertilization was applied (Corduneanu et al., 2015; Corduneanu et al., 2016). Drip irrigation was applied every two days; the water quantity was comprised between 200 and 300 m^3/ha, depending on air and soil temperature (Corduneanu et al., 2015; Corduneanu et al., 2016). The harvesting (Fig. 4) was performed at intervals and the yield was recorded separately for each variant.

3. Results and discussion

3.1. Effect of fertilizer distribution method over the tomato yield

Taking into account the average yield for the three consecutive years, the highest values were recorded for variant V1, with a difference of 35.74 t/ha, which is considered to be very significant (Table 2).

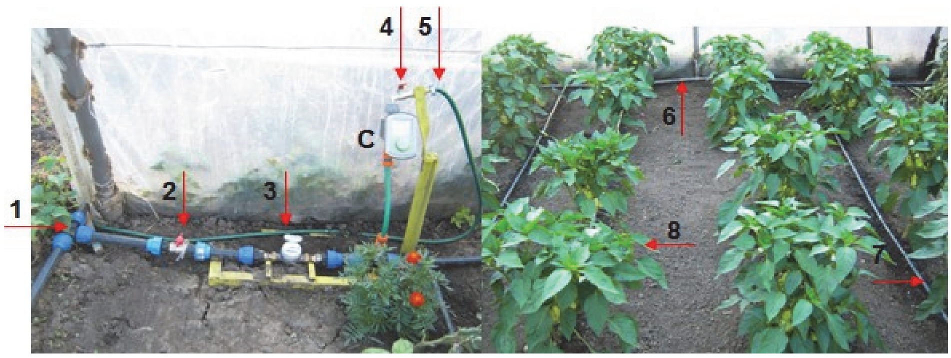

Fig. 3. Fertigation system: 1 – water supply; 2 – water valve; 3 – water flowmeter; 4 – valve fertilizer solution; 5 – hose for fertilizing solution; 6 – water distribution pipeline; 7 – watering band; 8 – plant; C – programmer

(a) (b)

Fig. 4. Harvest of sweet peppers (a) and tomatoes (b)

The coefficient of variation was comprised between 0 and 10%, which translates into a low variability compared to the average (Fig. 5). All the experimental variants are also strictly representative.

3.2 Effect of fertilizer distribution method over the sweet pepper yield

Table 3 presents the average values of the yield for three consecutive years. In statistical terms, the difference between variant V1 and the control variant is very significant (28.64 t/ha). Important differences were recorded for variant V2 (classic fertilization – 16.4 t/ha) and variant V3 (13.53 t/ha). Fig. 6 presents the results referring to the coefficient of variation; the data show a large variability, with coefficient values over 20%. Variant V_1 is moderately representative; variants V_2, V_3 and V_4 are largely representative.

4. Conclusions

For the both crops considered, fertigation (variant V1) has led to higher yields due to the controllable application of water and nutrients; this fertilization method is expected to have long term positive effects (reduction of soil compaction and salinization). The use of microorganisms-based fertilizers (variant V3) also has the potential to increase yield, especially for the tomato crop; however, for the sweet pepper crop, this fertilization method is overpassed by the classic method (spreading of solid fertilizer, variant V2).

These results prove that micro-irrigation with low amounts of water and controlled delivery, combined with the administration of fertilizers which enhance the microbiological soil activity (Nutrispore® - NPK (MgO) 30-10-10, Nutrispore® NPK (MgO) 15-10-30 and Nutrispore® NPK 12-48-8) could be taken into account as a fertilization method for growing crops under protected spaces and has the potential to significantly increase yield.

References

Alcantar G., Villarreal M.R., Aguilar A.S., (1999), Tomato growth (*Lycopersicon esculentum* Mill), and nutrient utilization in response to varying fertigation, *Acta Horticulturae*, **481**, 385-392.

Table 2. Average values of tomato yield (t/ha), 2015 – 2017

Variant	***Total yield** (t/ha)*	***Relative yield** (%)*	***Difference with respect to the control variant** (t/ha)*	***Significance of the difference***
V_1	123.04	140.93	35.74	***
V_2	94.16	107.85	6.86	ns
V_3	108.91	124.75	21.61	**
V_4	90.53	103.69	3.23	ns
V_5 Control)	87.30	100.00	0.00	ns

*LSD 5% =10.60 t/ha; LSD 1% = 15.42 t/ha; LSD 0.1% = 23.12 t/ha; ***-very significant; **distinct significant; ns- non-significant*

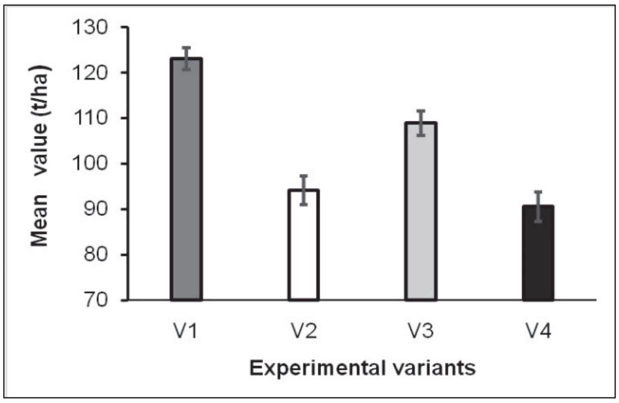

Fig. 5. Variability to the average of tomato production

Table 3. Average values of sweet peppers yield (t/ha), 2015-2017

Variant	***Overall yield (t/ha)***	***Relative yield (%)***	***Difference with respect to the control variant (t/ha)***	***Significance of the difference***
V_1	71.55	166.74	28.64	***
V_2	59.31	138.21	16.40	***
V_3	56.44	131.53	13.53	**
V_4	49.62	115.63	6.71	ns
V_5 (witness)	42.91	100	0	ns

*LSD 5% = 7.04 t/ha; LSD 1% = 10.24 t/ha; LSD 0.1% = 15.37 t/ha; ***-very significant; **distinct significant; ns- non-significant*

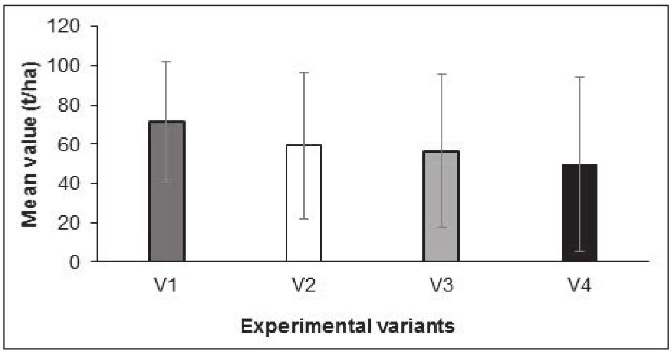

Fig. 6. Variability to the average of pepper production

Apahidean Al., Apahidean M., (2000), *Special Vegetables Growing* (in Romanian), vol. I, Risoprint Press, Cluj-Napoca, Romania.

Caruso G., Stoleru V., Munteanu N., Sellitto V.M., Teliban G.C., Burducea M., Tenu I., Morano G., Butnariu M.V., (2018), Quality performances of sweet pepper under farming management, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **47**, 458-464.

Chilom P., (2004), *Vegetables Growing Treaty*, Ceres Publishing House, Bucharest, Romania.

Corduneanu O., Țenu I., Stoleru V., Teliban G.C., Șovăială Gh., (2015), Research regarding the fertilization and drip irrigation of a greenhouse tomato crop (in Romanian), *Scientific Papers of U.S.A.M.V. Iaşi, Horticulture Series*, **58**, 69-74.

Corduneanu O., Țenu I., Stoleru V., Teliban G.C., (2016), Contributions to the improvement of the fertilization regime for a sweet pepper crop (in Romanian), *Scientific Papers of U.S.A.M.V. Iaşi, Horticulture Series*, **59**, 181-186.

Diacono M., Montemurro F., (2010), Long-term effects of organic amendments on soil fertility, A review, *Agronomy for Sustainable Development*, **30**, 401-422.

Doneen L.D., (1999), *Quality of Water for Irrigation*, Proc. of Conf. on Quality of water for irrigation, California, 56-76.

Grumeza N., Kleps C., (2005), *Irrigation Fittings in Romania* (in Romanian), CERES Publishing House, Bucharest, Romania

Hoban A., Luca E., Suciu S., (2007), Notions and formulas for calculating the water consumption of tomatoes in protected areas (in Romanian), *Agricultura Stiinta si practica*, **61-62**, on-line at: https://journals.usamvcluj.ro/index.php/agricultura/article/download/2878/2737

Hoza G., (2011), *Vegetables Growing Treatise - Distance Learning Textbook* (in Romanian), U.S.A.M.V. Bucureşti, 0-86.

ICPA, (2009), Methodologies for risk assesssment of agrophysical degradation (in Romanian), On line at: https://www.icpa.ro/proiecte/Proiecte%20nationale/RAMSOL/51-031_raport_4.pdf, 18.

Indrea A., Ciofu R., (1992), *Growing of Agricultural and Horticultural Crops* (in Romanian), Tehnica Agricola Printing House, Bucharest.

Ispas G.M., Roba C., Bălc R., Gligor D.M., (2020), The content of nutrients and contaminants in soil and vegetables cultivated in several greenhouses from Botoșani county and their impact on human health, *Carpathian Journal of Earth and Environmental Sciences*, **15**, 415-428.

Machado R.M.A., Serralheiro R.P., (2017), Soil salinity: effect on vegetable crop growth. management practices to prevent and mitigate soil salinization, *Horticulturae*, **3**, 30, https://doi.org/10.3390/horticulturae3020030.

Mirás-Avalos J.M., Rubio-Asensio J.S., Ramírez-Cuesta J.M., Maestre-Valero J.F., Intrigliolo D.S., (2019), Irrigation-advisor - a decision support system for irrigation of vegetable crops, *Water*, **11**, 2245, https://doi.org/10.3390/w11112245.

Pan H.Y., Fisher K.J., Nichols M.A., (1999), Fruit yield and maturity characteristics of processing tomatoes in response to drip irrigation, *Journal of Vegetable Crop Production*, **5**, 13-29.

Paudel D., Dhakal S., Parajuli S., Adhikari L., Peng Z., Xian Q., Shahi D., Avci M., Makaju Shiva O., Kannan B., (2020), *Use of Quantitative Trait Loci to Develop Stress Tolerance in Plants. Plant Life Under Changing Environment*, Academic Press, New York.

Popescu V., (2004), *Vegetables Growing Treaty*, Ceres Publishing House, Bucharest, Romania.

Savva A.P., Frenken K., (2002), *Planning, Development, Monitoring and Evaluation of Irrigated Agriculture with Farmer Participation*, In: *Irrigation Manual*, Vol. IV, Food and Agriculture of the United Nations (FAO), Sub-Regional Office for East and Southern Africa (SAFR), Harare, 15-96.

Stan N., Stan T., (2010), *Vegetable Growing* (in Romanian), "Ion Ionescu de la Brad" Publishing House, Iaşi, Romania.

Stoleru V., Munteanu N., Stoleru C.M., Rotaru L., (2012), Cultivar selection and pest control techniques on organic white cabbage yield, *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, **40**, 190-196.

Stoleru V., Munteanu N., Sellitto V.M., (2014), *New Approach of Organic Vegetable Systems*, Aracne Publishing House, Rome, Italy.

Wang H., Li X., Tan J., (2020), Interannual variations of evapotranspiration and water use efficiency over an oasis cropland in arid regions of North-Western China, *Water*, **12**, 1239, https://doi.org/10.3390/w12051239.

Williams W.D., (2001), Salinization: unplumbed salt in a parched landscape, *Water Science and Technology*, **43**, 85-91.

World Water Assessment Programme, (2012), *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk*, UNESCO, Paris, France.

WPS, (2021), World Population Statistics, 2021 U.N. Statistics Division of grouping countries into regions and subregions rather than into continents, On-line at: https://www.worldometers.info/world-population/