

INTERNATIONAL SCIENTIFIC JOURNAL

MECHANIZATION IN AGRICULTURE & CONSERVING OF THE RESOURCES



Issue 6
2019

Year LXV, ISSN print 2603-3704, ISSN web 2603-3712

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING
BULGARIAN ASSOCIATION OF MECHANIZATION IN AGRICULTURE



PUBLISHERS

SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY-4.0"
BUGLARINA ASSOCIATION OF AGRICULTURAL MACHINERY

ISSN (PRINT) 2603-3704, ISSN (ONLINE) 2603-3712

YEAR LXV ISSUE 6 / 2019

EDITORIAL BOARD

Chief Editor: Prof. Dr. eng Miho Mihov

Responsible secretary: Corresp. Memb. Prof. D.Sc. Hristo Beloev

MEMBERS:

Acad. D.Sc. Jemal Katsitadze – Georgia
Acad. D.Sc. Sayakhat Nukeshev - Kazakhstan
Acad. D.Sc. Volodymyr Bulgakov – Ukraine
Acad. D.Sc. Valeriy Adamchuk – Ukraine
Prof. Abdullah Sessiz - Turkey
Prof. Abdulrahman Al-soqeer - Saudi Arabia
Prof. Alexander Tokarev - Russia
Prof. Alexey Vassilev - Russia
Assoc.Prof. Angel Trifonov - Bulgaria
Prof. Anupam Kumar Nema - India
Prof. Ayrat Valiev - Russia
Prof. Barbro Ulén - Sweden
Prof. Carmen Puia - Romania
Prof. Cheslav Vashkievich - Poland
Prof. Cumhur Aydinalp - Turkey
Prof. Daisuke Higaki - Japan
Prof. Davor Romic - Croatia
Prof. Domenico Pessina - Italy
Dr. Finn Plauborg - Denmark
Assoc.Prof. Ganka Baeva - Bulgaria
Assoc.Prof. Georgi Mitev - Bulgaria
Prof. Georgi Tassev - Bulgaria
Prof. Haiyan Huang - China
Prof. Hoang Thai Dai - Vietnam

MEMBERS:

Prof. Iliya Malinov - Bulgaria
Prof. PhD Iurie Melnic - Moldova
Assoc.Prof. Ivan Ivanov - Bulgaria
Prof. Jan Szczepaniak - Poland
Prof. Komil Muminov - Uzbekistan
Prof. Krassimira Georgieva - Bulgaria
Prof. Maja Manojlović - Serbia
Prof. Mihail Iliev - Bulgaria
Prof. Mohammad Salem Al-Hwaiti - Jordan
Prof. Papamichail Dimitris - Greece
Prof. Pavel Tlustos - Czech Republic
Prof. Plamen Kangalov - Bulgaria
Prof. Ralph Meissner - Germany
Prof. Rossen Ivanov - Bulgaria
Prof. Svetla Rousseva - Bulgaria
Prof. Tadeusz Pawłowski - Poland
Prof. Tamara Persikova - Belarus
Prof. Valentina Kundius - Russia
Prof. Wojciech Tanaś - Poland
Prof. Yerbol Sarkynov - Kazakhstan
Prof. Zdenko Tkach - Slovakia
Prof. Zinta Gaile - Latvia
Prof. Zivko Davchev - Macedonia

The journal "Mechanization in agriculture" is continuer of the journals "Mechanized farming" (1948-1957), "Mechanization and electrification of agriculture" (1959-1980) and "Mechanization of agriculture" (1981-1991)

108, Rakovski Str., 1000 Sofia, Bulgaria
tel. (+359 2) 987 72 90, tel./fax (+359 2) 986 22 40,
office@stumejournals.com
WWW.STUMEJOURNALS.COM

CONTENTS

MECHANIZATION IN AGRICULTURE

CHANGE IN SOIL PROPERTIES AFTER 5 YEARS OF USING STRIP-TILL TECHNOLOGY

Assoc. Prof. Iwona Jaskulska, Prof. Dariusz Jaskulski 193

CONSERVING OF THE RESOURCES

MONITORING OF THE DRAINED SOILS, RUSSIAN PLAIN

Prof., Dr. Agricult. Kovalev I.V., Prof., Dr. Biol. Kovaleva N.O. 196

TREE-SOIL-WATER RELATIONSHIPS IN EUROPEAN BLACK ALDER FOREST - CASE STUDY

Prof. Paweł Rutkowski, Phd Student Monika Konatowska, Phd.Student Eng. Tomasz S. Wajsowicz 200

ACTIVATED CARBON OBTAINING FROM VARIOUS RAW MATERIAL / VIA CHEMICAL ACTIVATION FOR THE PURPOSE OF ENVIRONMENTAL PURIFICATION – OVERVIEW

Assist. Prof. Dr. Eng. Liliya Manoilova, Assist. Prof. Dr. Eng. Kamelia Ruskova 204

THE RESEARCH OF THE RAIN INTENSITY ADAPTATION TO THE CONDITIONS OF HYDROPHYSICAL CHARACTERISTICS OF THE SOIL FOR ECOLOGICAL AND ECONOMICAL IMPROVEMENT OF THE IRRIGATIVE EQUIPMENT

Iu. Melnic, A. Coronovschi, R. Ceban, A. Melnic 207

OPPORTUNITIES FOR AGROFORESTRY IN LATVIA

Mg. chem. Bardule A., Dr. silv. Lazdina D., Mg. oec. Makovskis K., Dr. silv. Bardulis A. 209

THE EFFECT OF MINERAL AND LIQUID ORGANIC FERTILISERS ON SOIL MINERAL NITROGEN AND CHLOROPHYLL CONTENT IN WINTER WHEAT LEAVES

PhD Stud. Danute Kvasoviene - Petraityte, Dr. Jurgita Ceseviciene, Dr. Ausra Arlauskiene, Dr. (HP) Alvyra Slepetiene 213

EVALUATION OF BACTERIAL ISOLATES FOR STIMULATING THE GROWTH OF YOUNG MELON (*CUCUMIS MELO* L.) PLANTS

Assist. Prof. Vasileva K. PhD., Ivanova Zh. PhD-student., Assoc. Prof. Tringovska I. PhD. 217

EVAPOTRANSPIRATION WITH STRAWBERRIES GROWN IN DRIP IRRIGATION CONDITIONS

Assoc. Prof. PhD R. Kireva, Prof. PhD M. Mihov 220

WATER PURIFICATION PRICE AND ACTUALITY OF THE PROBLEM OF WATER DEPURATION OF THE DNEPER ACCORDING TO THE THEORY OF SOCIAL WELFARE

PhD Stud. Holiachuk O. 223

ASSESSMENT OF SOIL CARBON STORAGE IN SAXAUL FORESTS IN THE BUIN ZAHRA DESERT OF IRAN.

Naseri H.R, PhD., Shakeri R, PhD., Yousefi Khanghah S, , PhD., Pour Rezaee J, PhD. 226

CHANGE IN SOIL PROPERTIES AFTER 5 YEARS OF USING STRIP-TILL TECHNOLOGY

Assoc. Prof. Iwona Jaskulska, Prof. Dariusz Jaskulski

Department of Agronomy, Faculty of Agriculture and Biotechnology, University of Science and Technology, Bydgoszcz, Poland
darekjas@utp.edu.pl

Abstract: In the years 2013-2018 at Agro-Land farm at Śmielin (53°09'04.0"N; 17°29'10.7"E; 93,8 m a.s.l.), Poland, the strip-till technology (soil strip loosening, fertilizer application and seed sowing in one pass hybrid machine Mzuri Pro-Til, Mzuri Ltd.) was compared with plough tillage and ploughless tillage, after which the seedbed was prepared, fertilizers were applied and then sowing was performed. After 5 years of using the strip-till technology, in comparison with plough and ploughless cultivation, the content of: organic carbon, available forms of macroelements, the share of water stability soil aggregates, as well as the number of: total bacteria, total fungi, earthworms increased in the top layer of the soil.

Keywords: ORGANIC CARBON, AVAILABLE MACROELEMENTS, WATER STABILITY SOIL AGGREGATES, BIOLOGICAL PROPERTIES

1. Introduction

Limiting the mechanical interference in soil and keeping plant residue and mulch on its surface are the essence of conservation agriculture. Its acreage and significance over the last decades has been increasing successively due to a need to achieve ecological goals by modern agriculture. The agricultural system dominates in many countries of South America, it is also common in Northern America, however, it covers only a small part of arable soils in Europe (Kassam et al. 2015, Reicosky 2015). Porwollik et al. (2019), however, indicate that potentially, in this area conservation tillage could be common. It is recommended due to more and more intensive environmental degradation processes. According to Lal (2015), it is manifested in soil structure degradation and its encrusting, a decrease in the content of organic matter, a decrease in biodiversity, a more intensified surface runoff and erosion, nutrient leaching. For that reason, the research of the soil degradation and protection processes, sharing knowledge and the results of the latest research, information providing and consulting actions for soil, water, and the air protection are essential (Dazzi et al. 2019). A lack of soil inverting, leaving a large amount of plant residue on the surface, decreasing the tillage depth, zone tillage are most environment conditions enhancing (Townsend et al. 2016). Such tillage method is provided by strip-till. Only narrow soil strips are tilled and provided with fertilizer and seeds. The inter-rows which provide for a minimum of 2/3 of the field acreage are not tilled, and mulch is found on the surface. It protects the soil from erosion and water – from evaporation (Morris et al. 2010). A high amount of mulch on the surface, however, makes a precise plant seeding more difficult for narrow row-spacing. For that reason, the technology is mostly applied for growing crops with a wide row-spacing, e.g. corn (Benincasa et al. 2017). Only the state-of-the-art machinery allows for sowing cereals in tilled soil strips with a simultaneous fertilizer application, Mzuri Pro-Til aggregate (Picture 1) which with one pass will till the soil strips about 12 cm wide and even 30 cm deep. Throughout the entire tilled soil area of each strip fertilizer is evenly spread, and at a specific depth the cereal grain is provided in two parallel rows. The width of non-tilled strips is 24 cm (Jaskulska et al. 2019).



Picture 1. Mzuri Pro-Til aggregate – strip-till technology

The objective of the research has been to evaluate changes in the soil properties after 5 years of the application of that technology in winter wheat and winter rapeseed growing.

2. Materials and Methods

2.1. Experiment site

The long-term field experiment was performed on the agricultural farm at Śmielin (53°09'04.0"N; 17°29'10.7"E; 93.8 m above sea level) in the kujawsko-pomorskie province, Poland, cooperating with the Department of Agronomy of the UTP University of Science and Technology in Bydgoszcz. The experiment was located on Cambisol with the grain-size composition in the layer 0-20 cm of sandy loam and silt loam. Prior to establishing the experiment the soil contained, on average: 11.4 g Corg kg⁻¹ of soil (elementary analyzer Vario Max CN, Elementar), 105 mg P kg⁻¹ of soil and 308 mg K kg⁻¹ of soil (according to Egner-Riehm), 103 mg Mg kg⁻¹ of soil (according to Schachtschabel), and pH_{KCl} was 6.1. The experiment area, according to the Köppen classification, is found in the zone of the humid continental climate (Peel et al. 2007). On average in the research period the annual precipitation was 520 mm, and temperature 8.6 °C.

2.2. Methods

The experiment was single-factor in the randomized block design. Three treatments were compared in four replications; tillage technologies, pre-sowing fertilization and plant seeding. Those were, respectively:

- strip-till technology (soil strip tillage, mineral fertilizers application into tilled soil strips, two-row seeding into those strips with a one pass of Mzuri Pro-Til 4T),
- plough technology (average-deep ploughing, pre-sowing mineral fertilization on the whole surface of the field, seedbed preparation, seed drilling),
- ploughless technology (soil tilling with the chisel, fertilization on the whole surface of the field, sowing with the use of combined cultivator and seed drill).

The plots were 250 m long and 12 m wide. In subsequent research years winter wheat and winter rapeseed were cultivated. Agrotechnical treatments were made with agricultural tools. After 5 research years for each treatment the following were evaluated: content of organic carbon and the available forms of macroelements – the methods as prior to the start of the experiments, the participation of the water stability soil aggregates, in the soil structure (with the method of wet separation using the Bakszejev apparatus), as well as the total count of bacteria (the method by Wallace and Lockhead 1950), total count of fungi (the method by Martin 1950), earthworms in the soil surface layer (0-15 cm).

3. Results and Discussion

The content of organic carbon and available forms of phosphorus and magnesium in soil after 5 years of the application of strip-till technology increased (Figs. 1, 2, 4).

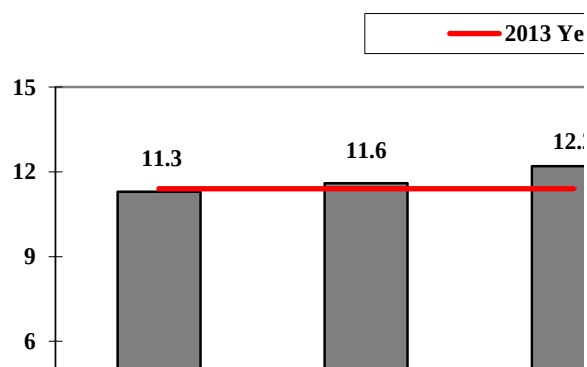


Fig. 1. Content of organic carbon (g C kg⁻¹ soil)

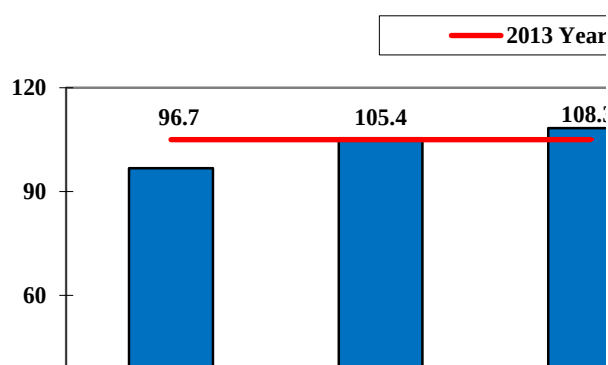


Fig. 2. Content of available phosphorus (mg P kg⁻¹ soil)

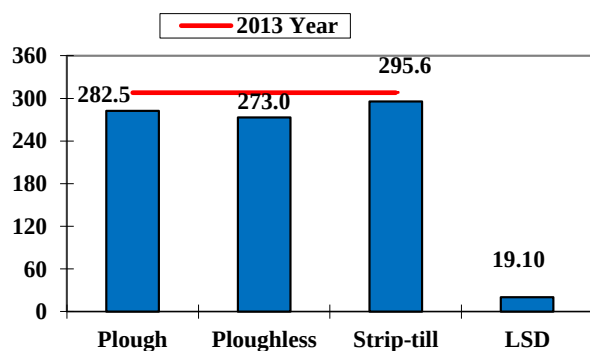


Fig. 3. Content of available potassium (mg K kg⁻¹ soil)

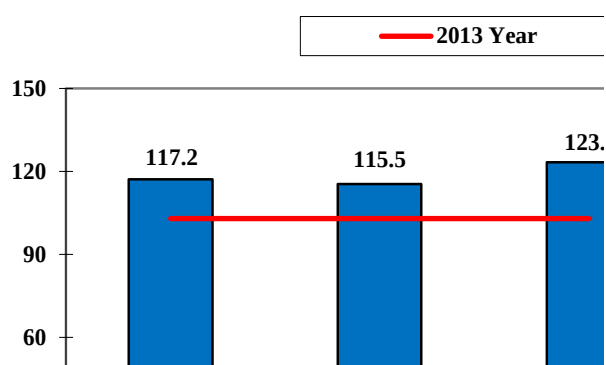


Fig. 4. Content of available magnesium (mg Mg kg⁻¹ soil)

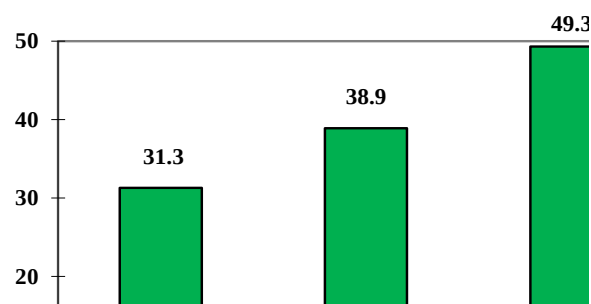


Fig. 5. Share of water stability soil aggregates (%) in the soil structure

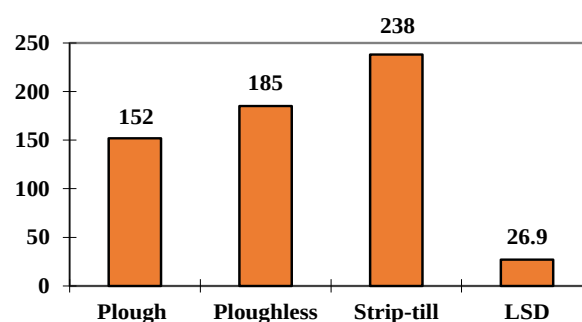


Fig. 6. Total count of bacteria (number of cfu·10⁷ g⁻¹ dm soil)

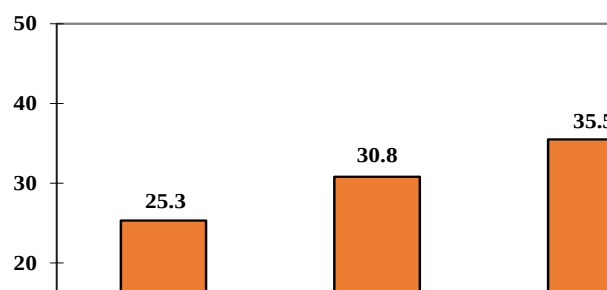


Fig. 7. Total count of fungi (number of cfu·10⁴ g⁻¹ dm soil)

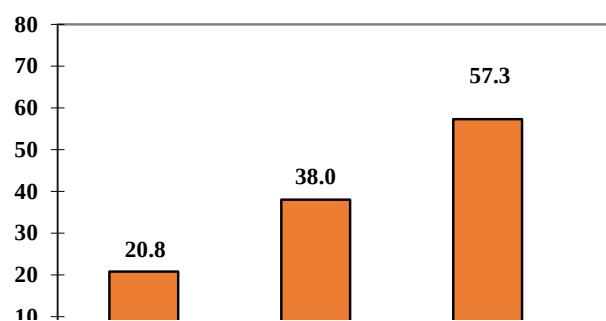


Fig. 8. Number of earthworms in the 0-15 cm soil layer (no. m⁻²)

As compared with plough tillage, this technology increased the content of available phosphorus in the upper soil layer significantly (Fig. 2), as compared with ploughless tillage – potassium and magnesium (Figs. 3, 4). Awale et al. (2013), performing three few-year experiments, in two of them also identified an increased accumulation of organic carbon in the soil surface layer with the thickness of 15 cm due to strip-till. The difference in its content, as compared with plough tillage, was about 4.0%. Many research results indicate that with no soil inverting and its intensive deep mixing, nutrients also get accumulated in the soil surface layer. Wróbel and Pabin (2008) have found it for the available forms of phosphorus and potassium.

The strip-tilled soil structure showed a greater participation of water stability soil aggregates (Fig. 5), which could have been due to the protective effect of plant residue and a limited effect of tillage tools on soil aggregates (Laufer et al. 2016).

In the present research not only the content of organic carbon but also the count of bacteria, fungi and the number of earthworms in the strip-tilled soil was significantly higher than in the plough tillage and ploughless tillage technology (Fig. 1, Figs 6-8). According to Hatfield and Walthall (2015), the role of microorganisms in developing the properties of soil and its fertility and productivity is very important. A positive role is also played by earthworms. Their number, biomass and diversity are greater in the soils not intensively tilled, especially not inverted by regular ploughing (Crittenden et al. 2015).

4. Conclusions

Strip-till technology (tilling of soil strips, application of fertilizers and seeding during one pass with the hybrid Mzuri Pro-Til) enhances the properties of the soil surface layer more than plough and ploughless tillage of the whole field supplemented with pre-sowing fertilization, the seedbed preparation and sowing. After 5 years of applying strip-till technology as compared with plough tillage or/ and ploughless tillage, the content of organic carbon and macronutrients in the soil surface layer increased. The total count of bacteria, fungi and the number of earthworms in the 0-15 cm soil layer were higher. In the soil aggregate structure, the share of water stability soil aggregates was higher.

References

Awale, R., A. Chatterjee, D. Franzen. Tillage and N-fertilizer influences on selected organic carbon fractions in a North Dakota silty clay soil. *Soil and Tillage Research*, 134, 2013, 213-222.

Benincasa, P., A. Zorzi, F. Panella, G. Tosti, M. Trevini. Strip tillage and sowing: is precision planting indispensable in silage maize? *International Journal of Plant Production*, 11, 2017, 577-588.

Carmelo, D., W. Cornelis, E.A.C. Costantini, M. Dumitru, M.A. Fullen, D. Gabriels, R. Kasparinskis, A. Kertész, G. Lo Papa, G. Pérès, J. Rickson, J.L. Rubio, T. Sholten, S. Theocharopoulos, I. Vasenev. The contribution of the European Society for Soil Conservation (ESSC) to scientific knowledge, education and sustainability. *International Soil and Water Conservation Research*, 7, 2019, 102-107.

Crittenden, S.J., E. Huerta, R.G.M. de Goede, M.M. Pulleman. Earthworm assemblages as affected by field margin strips and tillage intensity: An on-farm approach. *European Journal of Soil Biology*, 66, 2015, 49-56.

Dazzi, C., W. Cornelis, E.A.C. Costantini, M. Dumitru, M.A. Fullen, D. Gabriels, R. Kasparinskis, et al. The contribution of the European Society for Soil Conservation (ESSC) to scientific knowledge, education and sustainability. *International Soil and Water Conservation Research*, 7, 2019, 102-107.

Hatfield, J.L., C.L. Walthall. Soil biological fertility: Foundation for the next revolution in agriculture? *Communications in Soil Science and Plant Analysis*, 46, 2015, 753-762.

Jaskulska, I., A. Gałazka, D. Jaskulski. Strip-till as a means of decreasing spatial variability of winter barley within a field scale.

Acta Agriculturae Scandinavica, Section B – Soil and Plant Science, 69, 2019, 516-527.

Kassam, A., T. Friedrich, R. Derpsch, J. Kienzie. Overview of the worldwide spread of conservation agriculture. *Field Actions Science Reports – The Journal of Field Actions*, 8, 2015, 1-10.

Lal, R. Restoring soil quality to mitigate soil degradation. *Sustainability*, 7, 2015, 5875-5895.

Laufer, D., B. Loibl, B. Märlander, H-J. Koch. Soil erosion and surface runoff under strip tillage for sugar beet (*Beta vulgaris* L.) in Central Europe. *Soil and Tillage Research*, 162, 2016, 1-7.

Li, H.W., H.W. Gao, H.D. Wu, W.Y. Li, X.Y. Wang, J. He. Effects of 15 years of conservation tillage on soil structure and productivity of wheat cultivation in northern China. *Australian Journal of Soil Research*, 45, 2007, 344-350.

Martin, J.P. Use of acid, rose bengal and streptomycin in the plate method for estimating soil fungi. *Soil Science*, 69, 1950, 215-232.

Morris, N.L., P.C.H. Miller, J.H. Orson, R.J. Froud-Williams. The adoption of noninversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment - A review. *Soil and Tillage Research*, 108, 2010, 1-15.

Peel, M.C., B.L. Finlayson, T.A. McMahon. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 2007, 1633-1644.

Porwollik, V., S. Rolinski, J. Heinke, C. Müller. Generating a rule-based global gridded tillage dataset. *Earth System Science Data*, 11, 2019, 823-843.

Reicosky, D.C. Conservation tillage is not conservation agriculture. *Journal of Soil and Water Conservation*, 70, 2015, 103-108.

Townsend, T.J., S.J. Ramsden, P. Wilson. How do we cultivate in England? Tillage practices in crop production systems. *Soil Use and Management*, 32, 2016, 106-117.

Wallace, R., A. Lockhead. Qualitative studies of soil microorganisms. Ami-noacid requirements of rhizosphere bacteria. *Canadian Journal of Research*, sec. C 28, 1950, 1-6.

WRB. World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. IUSS Working Group WRB, World Soil Resources Reports No. 106, 2014, FAO, Rome.

Wróbel, S., J. Pabin. Effect of tillage system on macronutrient content in soil and maize plants cultivated in monoculture. *Roczniki Gleboznawcze - Soil Science Annual*, 59, 2008, 226-232. In Polish

MONITORING OF THE DRAINED SOILS, RUSSIAN PLAIN

Prof., Dr. Agricult. Kovalev I.V.¹, Prof., Dr. Biol. Kovaleva N.O.¹

¹Soil Science Faculty, Lomonosov Moscow State University – Moscow, Russia
kovalevmsu@mail.ru

Abstract: Main features of water region of Umbric Albeluvisols Abruptic and Gleyic Albeluvisols Abruptic displaying different rate in years with different moisturizing were studied. Two layers of surface water appear in soils in spring and fall, hence, the fields are decreased or crops die. Drainage is shown to eliminate surface water. Plastic drainage causes more intensive drainage effect than ceramic trench drainage in wet years. Drainage leads to an increase in specific surface area, total soil porosity, number of water stable aggregates, including those in the lower horizons, distribution of forms of iron compounds. Favorable conditions for the cultivation of crops, especially for grain crops, are formed on drained soils of the Nonchernozem region. Drainage exerted effect on the fractional and chemical composition and lignin of soils and Fe-Mn concretions.

Keywords: PLASTIC AND CERAMIC DRENAGE, HYDROLOGICAL REGIME, CROP YIELD, PROPERTY OF SOIL, ORSTEIN

1. Introduction

Fine carbonate-free loesslike loams are widespread in zone of broad-leaved forests of the southern nonchernozem region. Umbric Albeluvisols Abruptic and Gleyic Albeluvisols Abruptic with a low or moderate permeability (filtration coefficient – 0.1-0.2 m/day) are formed on these rocks. Umbric Albeluvisols Abruptic may be easily assimilated in agricultural production without any additional measures. The use of Gleyic Albeluvisols Abruptic and especially Luvic Stagnosols Dystric is complicated by their intensive overwetting (usually in spring). Unlike Umbric Albeluvisols Abruptic, the regims and properties of which have been examined very fully to understand their genesis and productive features, Gleyic Albeluvisols Abruptic need additional study. There is special interest in solving the following problems: (a) evaluation of the merit of draining Gleyic Albeluvisols Abruptic; (b) comparative study of drainage action of material drainage different types: particular trench ceramic and non-trench plastic drainage; (c) analysis of the hydrological regime variation in Gleyic Albeluvisols Abruptic as a result of drainage; (d) investigation of the influence of different types of drainage on the productivity of soils and the main zoned crops. These problems are very controversial for the conditions of the Nonchernozem region. Proven responses to them can evidently be obtained on a field station experiment.

2. Materials and Methods

Experimental reclamation test area («Kochkarevo», N 55° 06' 51" E 38° 18' 32") was created in 1987 year in the Moscow region. As a whole, the territory of the reclamation soil hydrological station is confined to the high-land area of the Moscow River-Oka plain, and geomorphologically it is smoothed moraine area. The upper layer of the modern deposits with a thickness of up to 10 meters is formed by cover loess-like carbonate-free loams, under the series of which moraine loams and lays are bedded. The moraine deposits are underlain by a veneer of Jurassic clays. The latter rest on the Middle Carboniferous limestones. The groundwater is confined to this horizon. All studied soils are located on a modern plowed field. In Gleyic Albeluvisols Abruptic signs of hydromorphism appear in the form of rare Fe-Mn concretions in the clearly expressed horizon E; siliceous powder throughout the entire profile, spots of gleiing in horizons BC and C a depth of 100 cm, large dark-colored spots of amorphous iron hydroxides and manganese from the same depth.

Six autonomous drainage systems were constructed in the test area, each of which had an area of 2.0-4.0 hectares with observation shafts and drops at the exit of a collector for measuring the drainage runoff. The system was constructed in threefold repetition for each experiment variant. The non-trench plastic drainage was installed by an MD-4.5 drain layer to a depth of 1-1.2 m, and the ceramic trench drainage was installed by an Etts-202 drain layer to the same depth. In both variants, the same interdrain distance of 16 m was maintained. All studied soils are located on a modern plowed field. Soils had similar causes of bogging (surface runoff) and were

formed on rocks with close or similar texture – coarse silty-clayey sandy loam [1].

We examined the ecological-hydrological conditions typical of non drained Umbric Albeluvisols Abruptic and Gleyic Albeluvisols Abruptic with natural zonal water regime, as well as Gleyic Albeluvisols Abruptic drained. The elements of the water regime were studied during the 30 years (1988-2018).

The water regime was studied in early spring (for distinguishing two layers of temporary perched water) by drilling using casing tubes and subsequent thermostatic weighing of samples. The redox potential was measured by the potentiometer with the platinized electrode [1].

The studies of the density of the solid phase, bulk density, soil texture were carried out using conventional methods [3]. To determine maximum field water holding capacity (MWC) sites 4 m² in size were laid out; the sites were covered with ruberoid, plastic film and then with 20-30 cm layer of soil after complete saturation with snowmelt water. Soil moisture was determined at 2-5 day intervals. The state of moisture equilibrium determined at three (sometimes, four) sampling dates was indicative of the fact that the soil moisture had reached maximum field water holding capacity. The porosity of aggregates 3 to 5 cm in diameter was determined by kerosene method. The main hydrophysical characteristic was determined by tensiometric method (using a horizontal capillarimeter), by the method of sorption equilibrium, and by calculations [3].

The average crop yield values for the three systems of ceramic and plastic drainage were obtained (t / ha) by direct combining from the area of each system (2-4 ha).

3. Results and Discussion

3.1. Water regime of drained and undrained soils.

Components of the water regime of Gleyic Albeluvisols Abruptic were studied over a period of five years strongly differing in the amount of precipitation. The provision of precipitation during the growing season (April to October) was 86, 33, 49, 9, and 94 %, respectively, the corresponding values for the annual provision of precipitation were 73, 46, 25, 30, and 92 % (Figure 1). The wetness regime of Gleyic Albeluvisols Abruptic is distinguished by significant contrast. Independently of the wetness of the year, immediately after snowmelt, the entire profile was flooded. This state of the soil was also observed in autumn in the period of abundant precipitation. The soil wetness in this case was usually in the interval between the FC (maximal field moisture capacity) and MWC (full moisture capacity). At the beginning and middle of the year, the wetness of the soil (especially in surface horizons) dropped below the FC (or below 0.78 MWC). In individual years in layers 30-50 cm thick for a brief period, it dropped to the permanent wilting point (PWP).

A typical feature of the wetness regime of nondrained soils is the development of a two-stage perched water table in their profile. Its upper stage is confined to the plow layer, and the lower was situated at the depth of 70-75 cm.

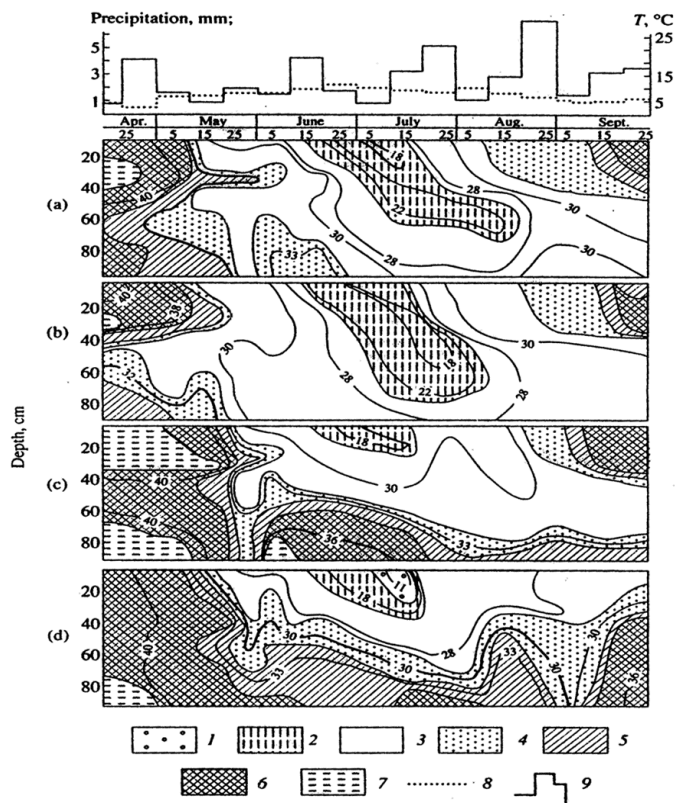


Fig. 1. Elements of the water regime of nondrained and drained soils (moisture in volumetric percentage and categories). Soils: (a) Gleyic Albeluvisols Abruptic drained with ceramic drains; (b) Gleyic Albeluvisols Abruptic drained with plastic drains; (c) Gleyic Albeluvisols Abruptic nondrained (control); (d) Umbric Albeluvisols Abruptic nondrained. Moisture categories: (1) below permanent wilting point (PWP); (2) from PWP to moisture of capillary bond (MCB); (3) from MCB to 0.95 field capacity (FC); (4) 0.95 FC to FC; (5) FC to 1.05 FC; (6) 1.05 FC to maximum water capacity (MWC); (7) MWC, perched water table; (8) air temperature; (9) precipitation.

Between these two horizons of total inundation, there are zones with wetness equal to the MWC-FC. Observations show that drainage in wet, moderate, and dry years has very substantial influence on the wetness regime of Gleyic Albeluvisols. Its action in these soils appears in the fact that it completely or almost completely eliminates the presence of free gravity moisture at the level of full flooding (MWC). In the presence of drainage in Gleyic Albeluvisols, not only is the two-stage state of the perched water table eliminated, but the gravity moisture at the level of FC also disappears from the lower horizons. In this case, the soil wetness throughout most of the warm period turns out to be equal to MCB (wetness of capillary breach)-FC (field capacity).

The results of observations of the wetness regime of soils let us identify definite differences in the action of ceramic trench and plastic non-trench drainage. In wet years, according to our data, plastic drainage causes more intensive drainage of the soils than ceramic trench drainage. Thus, throughout the entire warm period in soils drained by non-trench plastic drainage, the moisture is preserved longer in the plow layer of the profile at the level of 0.77 FC-FC, whereas in its deep layers the periods of wetting above the FC become shorter. The latter increases the accumulating capacity of the soils and turns out to be the cause of the relative decrease in the volume of the drainage runoff and maximal runoff moduli. More intensive decrease in wetness of Gleyic Albeluvisols Abruptic with the application of non-trench plastic drainage is observed not only in wet years, but also in moderate and dry years. This lets us acknowledge that, without applying trench filters in Gleyic

Albeluvisols Abruptic, non-trench plastic drainage has the same (or more intensive) hydrological action as trench ceramic drainage. Independently of the type of drainage, it always turns out to be the cause of deep drainage of surface horizons in the period of summer drought. The soil wetness at the level of PWP-MCB in moderate and dry years is traced in the series of 60-80 cm. This wetness can be preserved stably in the profile of drained Gray Forest soils for 1-1.5 months, whereas in the extremely dry year of 1992 for approximately the same period and at the level of less than PWP (below permanent wilting point). In this case, the deepest drainage effect takes place by the non-trench plastic drainage. As a whole, in the early summer and mid-summer period, Gleyic Albeluvisols (both drained and undrained) have a similar wetting character. The surface layers underwent intensive drainage is this period. Plants often experience a moisture deficit in moderate and dry years. Precipitation does not cover the moisture deficit and accumulated mainly in the layer of 0-20 cm in the form of capillary-perched moisture.

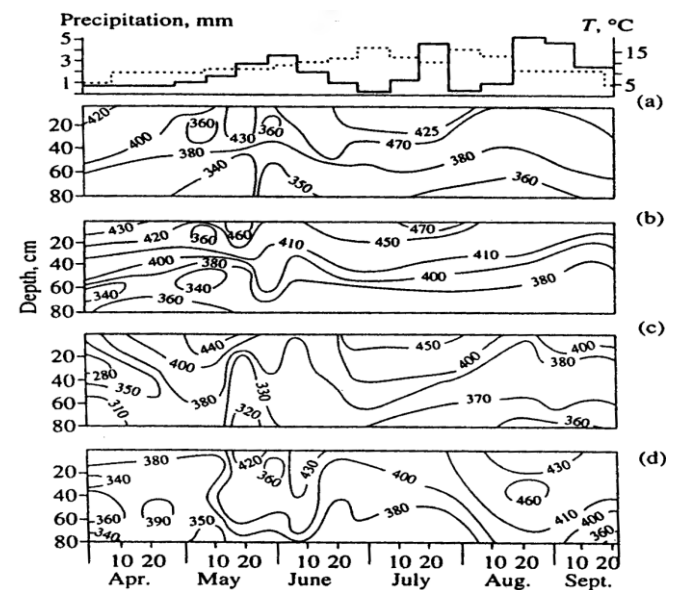


Fig. 2. Redox potentials (mv) in nondrained and drained soils: (a) Gleyic Albeluvisols Abruptic drained with ceramic drains; (b) Gleyic Albeluvisols Abruptic drained with plastic drains; (c) Gleyic Albeluvisols Abruptic nondrained (control); (d) Umbric Albeluvisols Abruptic nondrained.

All this allows us to make a general conclusion that drained soils, on one hand, and undrained as well as Umbric Albeluvisols, on the other, are essentially different in basic components of their water regime, especially in springtime. Thus, at this time, Umbric Albeluvisols Abruptic with a natural water regime are characterized by a certain decrease in the redox potential down to 280 to 310 mV and by the development of anaerobic conditions (Table 2). In summer, soils of the first stages of hydromorphism typically have similar redox potential values. Providing the maximal discharge of gravitational water in spring, drainage equalizes the redox potential values along the whole soil profile throughout the warm (growing) period.

3.2. Productivity of drained and undrained soils.

It has been established that, throughout the entire cycle of investigation, the yield of agricultural crops in undrained Gleyic Albeluvisols Abruptic was always substantially smaller than on drained soil. This circumstance confirms the ecological and economic merit of draining Gleyic Albeluvisols Abruptic for cultivated localized crops. It was established (Table 1), that crop yields on non-draining agrogray soils was always significantly less than on drained soils by different types of drainage. Only moisture-loving grasses in these conditions can be cultivated without damage to their crops. Grass (oats silage) in summer sowing in an extremely dry year on undrained soils gave almost 2 times higher yield than on drained soils. All other cultures experienced oppression from waterlogging. So, the yield of spring crops due to the application of drainage was higher by 12 %; winter grain-by 17-28 %. In

extremely dry years, oats for silage during the summer sowing period during the growing season was in a depressed state due to insufficient moisture of the arable horizon. Soil moisture for more than a month was in the range of less than PWP (Figure 1), which led to a decrease in yield. It should be emphasized that on Gleyic Albeluvisols Abruptic without drainage very natural conditions are developed, which are determined mainly by precipitation. Therefore, crops are unstable and they fluctuate in a very wide range. For example, the grain harvest was from 0.62 to 3.98 t / ha on the non-drained soils for the period 1989-2017. However, it was equal to 4.67 t/ha (3.51 – 5.10 t/ha) on the background of plastic and ceramic drainage (5 % level of significance). The task of drainage is, first of all, to create favorable conditions for the implementation of agricultural works and eliminate excess moisture during the growing season. Therefore, rapid elimination of excess moisture leads to higher yields. So, on the plots with pottery trench and with plastic trenchless drainage with winter grain runoff stopped at April (16.04), yield was 5.10 and 6.57 t/ha. However, landfills, where cessation of flow was observed in May (05.05), yields were 2.94 and 3.47 t/ha. Thus, the faster the soil was released from excess moisture in the wet year, then the yield was higher.

Table 1: Productivity of agricultural crops on non-drained and drained soils (t/ha).

Provision of precipitation	Agricultural crop	Gleyic Albeluvisols Abruptic (Agrogray soils)			
		Umbric Albeluvisols Abruptic	Gleyed soils		
			Non-drained	Plastic drainage	Ceramic drainage
dry year	vico-cereal mixture for grain	2.64	-	2.35	2.43
moderately wet year	winter wheat	5.66	3.98	4.67	5.10
wet year	winter wheat	4.94	0.62	4.50	4.46
moderately wet year	barley	-	29.0 ^a	3.51	3.55
dry year	perennial grass ^b	21.4	13.1	7.23	7.27

^a Sowing a month later due to full watering.

^b Summer sowing July 20

3.3. Some physical properties of drained and undrained soils.

All soils (undrained and drained) are formed on rocks with similar or identical soil-particle distribution: large silt to muddy coarse loam. The soil-forming rock of all soils is dominated by the large silt fraction (0.05-0.01 mm), that is, 54.8-55.8 percent. The mud content is 19.2-20.1 percent, that of physical clay (<0.01 mm) is 26.8-27.7 percent, and that of physical sand is 72.3-73.2 percent. The investigated soils are comparable in terms of soil-particle distribution. The loss of mud from the upper horizons weakens somewhat with the growth of the degree of hydromorphism. Thus, in Umbric Albeluvisols Abruptic, the mud content in horizon Ap is 14.9-22.0 percent, and in the undrained Gleyic Albeluvisols Abruptic, it is 21.9-24.7 percent. Thus, the degree of hydromorphism of the soils evidently determines the process of clay texture differentiation of the profile. Statistically significantly noticeable changes in the soil-particle distribution of clay was manifested in zonal Umbric Albeluvisols Abruptic, as well as in Gleyic Albeluvisols Abruptic drained, but only in the 30th year of the drainage action. In the literature there are some indications of active migration of clay caused by drainage. However, no appreciable effect of the drainage system was found in the third year and in the 14th year of its operation (both ceramic and plastic systems) which could manifest itself either in the changes of clay and physical clay content in the soils, or in the middle of drain spacings, or in immediate proximity to the drains (within 1 m). At

the same time, under the influence of drainage in the first years of its operation, the slightly dove-colored tint in horizon EB weakened and the rust-ochre spots in horizon Ap and EB disappeared. In the summer period, these differences in the upper horizons are not very noticeable. In the lower horizons, the bright dove-gray to gray color of the gleiing spots usually changes to gray.

The absolute values of density of the solid phase of the soil are practically identical in soils of different degrees of gleying and in soils drained by different types of drainage. The consistency of the plowed layers does not differ significantly. The illuvial horizons of undrained Gleyic Albeluvisols Abruptic have high values of this parameter compared to the drained variants of this soil and Umbric Albeluvisols Abruptic. The total porosity of the illuvial horizons of undrained Gleyic Albeluvisols is 2-9 percent smaller than that of Umbric Albeluvisols and drained Gleyic Albeluvisols. Total porosity of illuvial horizons of the non-drained soil was shown to be 2-3% lower than that of Umbric Albeluvisols and drained Gleyic Albeluvisols. The porosity of 3-5 mm aggregates in the Umbric Albeluvisols was 3-6% higher as compared with that of drained and non-drained soils, except illuvial horizon at a depth of 50-60 cm. In drained soils only a trend towards increased porosity was observed due to the effect of various types of drainage.

Specific surface is an integral index of the mineralogical and soil texture composition, humus content. The specific surface area values are significantly higher in drained soils than in zonal and in non-drained Gleyic Albeluvisols (Table 2). Thus, specific surface area of the plow horizon of Gleyic Albeluvisols Abruptic drained by plastic drainage increased by 38-40 %, subsurface horizon – by 7-11 %, illuvial – by 3-5 % as compared with the Umbric Albeluvisols Abruptic. It should be emphasized that in all soils in question the outer surface area exceeded the inner one. Probably, various mechanisms responsible for the increase of the pore space can be in effect here. First, the transformation of mobil bivalent forms of Fe and Mn to insoluble trivalent forms due to drainage, thus favouring the aggregation of the horizons, were observed. Second, drainage caused an appreciable increase of filtration coefficient values from 0.1-0.3m /24 hrs to 1.00 m/24 hrs and drained soils are characterised by more intensive percolated water regime, increased removal of clay and iron. Third, aerobic conditions in drained soils are favourable for humification processes [2].

Table 2: Specific Surface area of Albeluvisols.

Horizon	Depth (cm)	Specific surface area (m ² /g)		
		Total	Outer	Inner
Umbric Albeluvisols Abruptic				
Ap	10-15	55.1	40.2	15.1
E	29-31	91.8	75.4	16.5
B1	60-65	111.3	79.6	32.7
B2	110-115	92.3	65.3	28.4
Gleyic Albeluvisols Abruptic (non-drained)				
Apg	10-15	88.9	59.5	29.4
EBg	30-35	102.7	71.2	31.3
B1g	60-65	109.9	70.4	38.5
B2g	110-115	94.5	53.5	41.4
Gleyic Albeluvisols Abruptic (plastic drainage)				
Ap	10-15	86.6	47.9	38.7
EBg	30-35	119.3	80.2	39.1
B1g	60-65	122.9	78.7	44.2
B2g	110-115	112.1	83.1	28.9
Gleyic Albeluvisols Abruptic (ceramic drainage)				
Ap	10-15	97.6	59.6	38.0
EBg	30-35	119.3	72.3	47.0
B1g	60-65	115.7	72.6	43.1
B2g	110-115	112.1	77.8	34.3

The effect of the drainage in the third year of operation of the drainage system decreased the content of amorphous iron in the 0- to 30-cm and 30- to 85-cm layers of the drained soil profiles. For example, the contents of amorphous iron in these layers of the gleyic soils significantly differed from those in the control (undrained gleyic soil) at a significance level of 5% when plastic drains were used and at a significance level of 10% for pottery drains. The dynamics of the amorphous iron in the different years of the drainage aftereffect was of nonlinear character. In the 14th year, the content of amorphous iron in the humus horizons increased again (Table 3). This phenomenon was also observed for the undrained soils. The content of oxalate-extractable Fe decreased in the lower illuvial horizons of the drained gleyic and undrained deeply gleyed soils. This distribution of amorphous Fe can be due to the biochemical accumulation in the upper horizons. It is known that the biochemical accumulation of Fe is caused by the partial hydration of its strongly crystallized forms and their transformation into poorly crystallized and amorphous forms due to input from plant waste or the rhizosphere. Organic substances inhibit the crystallization of sesquioxides, because Fe complexes with humus acids and acids from root exudates are formed with the participation of microorganisms and hamper the crystallization of Fe oxides. In our case, the rhizosphere productivity of winter wheat in the 0- to 32-cm layer in the 3th year of operation of the drainage system was 2.33 t/ha in the undrained gleyic soil and 5.32 t/ha (average from four polygons) in the drained gleyic soil. In the 14th year, the rhizosphere productivity of perennial grasses with undersown barley was 9.89 and 16.32 t/ha for the undrained and drained soils, respectively.

Table 3: Forms of iron compounds (%) in drained and non-drained Gleyic Albeluvisols Abruptic.

Horizon, depth (cm)	Fe ₂ O ₃ , % in annealed sample (Fe)	Tamm's solution, % of soil weight	
		In the 3 th year	In the 14 th year
		of operation of the drainage system	
Umbric Albeluvisols Abruptic			
Ap 10-15	3,12	0,17	0,23
E 29-31	3,78	0,15	0,23
B1 60-65	4,93	0,18	0,11
B2 110-115	5,07	0,10	0,06
Gleyic Albeluvisols Abruptic (non-drained)			
Apg 10-15	3,80	0,33	0,39
EBg 30-35	4,68	0,29	0,24
B1g 60-65	4,72	0,24	0,25
B2g 110-115	4,29	0,17	0,23
Gleyic Albeluvisols Abruptic (plastic drainage, n=6; ceramic drainage, n=6)			
Ap 10-15	4,35	0,32	0,41
EBg 30-35	4,68	0,28	0,25
B1g 60-65	4,69	0,23	0,20
B2g 110-115	4,21	0,16	0,16

The evolution of the soil cover may be gradual or very distinctive. Soil drainage causing the deep transformation of the hydrological regime determines the subsequent evolution of the soil cover. For a relatively short time (eight years), drainage exerted a very prominent effect on the total soil mass, morphology, and fractional and chemical composition of Fe-Mn concretions. In gleyic Albeluvisols Abruptic, during the first years of the drainage aftereffect, these changes (relative to the control) were manifested in the following. First, the total mass of ortsteins decreased sharply (by 2 to 2.3 times). Second, the content of large Fe-Mn concretions decreased (by 30 %), while the content of small medium-sized (2-3 mm) concretions decreased insignificantly (12-17 %). Third, the content of carbon and nitrogen, iron and manganese in concretions from drained soils decreased (Table 4). Drainage caused a deep transformation of lignin in the Fe-Mn nodules, especially in the coarse fractions of concretions. The mineralization of lignin aromatic compounds under aerobic conditions was accompanied by the significant increase in the share of phenol acids [2].

Table 4: Chemical composition (%) of ortsteins and ortstein mass (g/100 g of soil) in gleyic Albeluvisols Abruptic in the 0-15 cm of the Ap horizon non-drained and drained soils.

Element , %	1989-1992 years (n = 10)			2015-2018 years (n =10)			No du le•
	Fractions, mm						
	1-2	2-3	3-5	1-2	2-3	3-5	
	Gleyic Albeluvisols Abruptic (non-drained)						
C, %	1,75	1,73	1,60	1,68	1,66	1,55	0.26
N, %	0,15	0,15	0,14	0,14	0,14	0,14	±
C/N	12,0	11,7	11,5	11,9	11,7	11,3	0.02
Gleyic Albeluvisols Abruptic (ceramic drainage)							
C, %	1,62*	1,50*	1,43*	1,28**	1,00**	0,94**	0.84
N, %	0,15°	1,40°	1,40°	0,12**	0,11**	0,10**	±
C/N	10,8	10,7	10,4	10,2	10,2	9,5	0.06
Gleyic Albeluvisols Abruptic (plastic drainage)							
C, %	1,65*	1,56*	1,51*	1,31**	1,17**	0,10**	0.97
N, %	0,14°	0,14°	0,14°	0,12**	0,12**	0,11**	±
C/N	11,5	11,2	10,7	10,5	10,0	9,4	0.05

* – statistically significant reduction of carbon content to control at p < 0.95;

° – statistically significant reduction of nitrogen content to control at p < 0.90;

** – statistically significant reduction of carbon and nitrogen content in relation to the first years (1989-1992) of drainage aftereffect at p < 0.95

• – nodule (ortstein) mass, g/100 g of absolutely dry soil in relation to the first years (1989-1992) of drainage

4. Conclusion

The data obtained show that the modern agronomical utilization of Gleyic Albeluvisols Abruptic in an undrained state take place under conditions of a natural, very unstable water regime. This leads to practically complete soaring of the yield of grain crops in wet years or its decrease in moderate and dry years. It is established that drainage completely eliminates the formation of the two-stage perched water table which is typical of these soils under natural conditions. The tendency of more intensive influence of non-trench plastic drainage on wetness regime of these soils is established. In drained soils weakening of morphochromatic features of gleyfication is observed (as the disappearance of ochreous spots, with bluish-gray color turning to gray in the lower horizons), as well as the decrease of the bulk density; water stability of aggregates increases, in illuvial horizons the increase of the volume of aeration, infiltration, and water conducting pores occurs. Thus, favorable conditions for the cultivation of crops, especially for grain crops, are formed on drained soils. In the 14th year of the pottery and plastic drainage, the following took place: (a) The removal of nonsilicate iron from the upper horizons was observed. (b) The content of amorphous iron in the humus horizons increased, probably due to the biological accumulation and transformation of Fe-Mn ortsteins, which was also typical for undrained soils in the close vicinity of the drained soils. (c) The increase in the specific surface of the drained soils was due to the disaggregation of silt because of the removal of nonsilicate iron.

Acknowledgements

We thank Russian Scientific Fond for the financial support of this investigation (grant 17-14-01120).

5. Literature

- [1] Zaidelman F.R., Kovalev I.V. Effect of drainage on the status and fabric of concretions in gray forest gleyed soils. Eurasian Soil Science. 1998. Vol. 31. no. 9. P. 996–1004.
- [2] Kovalev I.V., Kovaleva N.O. Biochemistry of lignin in soils of periodic excessive moistening (from the example of agrogray soils // Eurasian Soil Science. 2008. Vol. 41, no. 10. P. 1066–1076.
- [3] Teorii i metody fiziki pochv (in Russia). 2007 (Moscow: «Grif and K» Publishing House) 616 p.

TREE-SOIL-WATER RELATIONSHIPS IN EUROPEAN BLACK ALDER FOREST - CASE STUDY

Prof. Paweł Rutkowski¹, Phd Student Monika Konatowska¹, Phd.Student Eng. Tomasz S. Wajsowicz¹
Faculty of Forestry, Department of Forest Sites and Ecology, Poznań University of Life Sciences, Poland¹
monika.konatowska@mail.up.poznan.pl

Abstract: Environmental factors, including temperature and air humidity, undoubtedly affect the life processes of plants, but in the black alder an additional factor responsible for the tree activity is the seasonal variability of soil moisture. In the conducted research, the activity of the tree, expressed as the conductivity measured in Hz, was seven times lower, in the period when the water level in 2018 was high, than in the analogous period in 2019, when the level of groundwater was low. In the period from January 1 to May 31, 2018, the maximum value of conductivity reached 601 Hz, while in the analogous period of 2019, 4229 Hz. Differences in the soil moisture also affected the length of the dormancy period of the tree, which in the first observation season lasted from November 2017 to April 2018, while at the turn of 2018 and 2019, the tree activity stopped for just a few days when air temperature dropped on January 23, 2019 to -9.8 °C.

Keywords: ALNUS GLUTINOSA, TREE CONDUCTIVITY, GROUND WATER, DORMANCY PERIOD

1. Introduction

Alnus glutinosa (L.) Gaertn., known as common or black alder, is a broadleaved tree native to most of Europe. It is adapted to a wide range of temperatures and is relatively frost-tolerant. It can grow well in continental climates but requires a high availability of water to thrive. It can be found on a wide range of soil types including poor soils and even coarse sands and gravels if the moisture is adequate, although it does not grow very well on calcareous soils. Atmospheric humidity must remain high during all phases of its reproductive cycle and the roots are well-adapted to growing on very wet soils: it can survive flooding better than most other forest tree species [1].

Black alder is a typical water-demanding species because its leaves have no mechanism for controlling transpiration [2]. In Germany, Herbst et al. [3] demonstrated that evapotranspiration in a black alder stand is equal to total annual rainfall. This means that the tree can suffer from water deficits during dry and warm periods in summer. In consequence if growth is to be satisfactory, and access to groundwater is not possible, annual precipitation must be high. Based on their local observations, Fremstad [4] for Norway, Lhote [5] for the Atlantic Pyrénées in France and Mac Vean [6] for Wales have fixed this minimum at 1500 mm.

The described ecological requirements of the black alder cause that this species may have a different life cycle than most deciduous temperate species whose activity is dictated by the changing seasons. In the black alder, the seasonality of hydrological conditions may be an additional factor. Therefore, the research hypothesis in this paper assumes that the activity of the black alder in the temperate zone depends not only on factors related to the temperature or humidity proper to the changing seasons, but also to the changes of ground water table during the seasons and in the course of years. Verification of this hypothesis became the goal of the research.

Although black alder is not particularly common (less than 1% of forest cover in most countries), it is an important component in open landscapes, especially along river banks and in marshy areas [1]. The share of stands from *Alnus glutinosa* in the area of Polish forests is estimated at approx. 5% [7]. They occur mainly in lowland areas (up to 300 m above sea level), in three forest habitat types: bog mixed broadleaved forest (LMb in Polish forest site type classification), alder forest (OI) and ash-alder forest (OIJ) [8], occupying respectively: 0.7, 2.4 and 0.8% of the area of lowland forests [7]. The following plant communities correspond in Poland respectively to the listed forest habitat types: *Sphagno squarrosi-Alnetum*, *Ribeso nigri-Alnetum* and *Fraxino-Alnetum* [9]. Soils of bog mixed broadleaved forests are mainly mesotrophic peats composed of plants like sedges, associated with sphagnum mosses, accompanied by aquatic and amphibious communities. The surface layer of the soil is often desiccated, forming muck-peat soils. Soils

of alder and ash-alder forests present a large and diverse range of eutrophic organic and organic-mineral soil types.

Soil humidity of bog mixed broadleaved forests depends mainly of amount of rainfalls. Soils of alder and ash-alder forests, except of amount of rainfalls, are influenced of ground water table, which ranges, in natural conditions, from water above soil surface to the depth of 0.5 m below the surface of the ground. The lower level of groundwater testifies to the drainage of the habitat [10].

The studies conducted in US by DeWald and Steiner [11] on 48 populations of *Alnus glutinosa* coming from over most the European range of black alder showed that in the same Pennsylvania site conditions the means for almost all populations varied by no more than 4 days in budburst timing. In this, black alder resembles Scots pine (*Pinus sylvestris*), which is also relatively uniform in budburst timing over the central European portion of its range. The other notable result is that most populations outside this region were later to burst bud, so that trees from such climatically diverse locations as Italy, Scotland, Norway, and the southern Russia burst bud at almost the same time. On the other hand Pliūra nad Kundrotas [12] observed earlier and later bud flushing of different tested populations and that these populations keep the same phenology behavior over different test plantations. Turchina [13] in long-term studies revealed dependence of the phenological phase duration under the combined influence of the heat and moisture conditions. Finally, different results of different researchers may be by the effect not only the temperature and humidity interactions, but different ground water level during years too. Revealing these wider interactions is the aim of this study.

2. Objects and methods

The research area is situated in lowland part of Poland in Zielonka Experimental Forest (Poznań University of Life Sciences, Faculty of Forestry) (Fig. 1). The forest address is: 01-01-1-01-73-d. Total area of research field is 1.13 ha (11300 m²). The co-ordinates of the middle of the plot are: 17°03'07.0"E and 52°31'32.2"N. The stand is composed of *Alnus glutinosa*, 55 years old [14], data modified to 2019-01-01). Studied alder forest is situated in the middle of bigger forest complex and is surrounded by oak, hornbeam and pine forests.

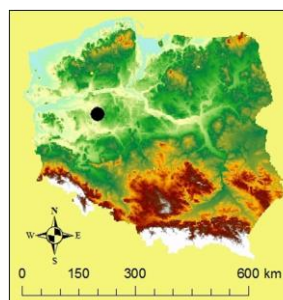


Fig. 1. Map of Poland with marked research area (black dot)

Wielkopolska, where the research area is situated, as a one of Polish geographical and historical regions, is considered to be the one of the driest parts of Poland. This is mainly the result of low annual precipitation amounts, although human activity played a significant role in the unfavorable water balance. The average annual rainfall for Zielonka's meteorological station (5 km NE of research area), for the years 1986-2008 was 525 mm. Although the trend line for precipitation is relatively constant, the annual sum of rainfalls differs significantly in individual years (Fig. 2). The average annual air temperature is 8.3 C°.

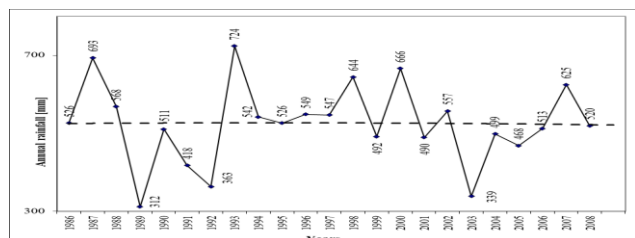


Fig. 2. Annual sum of rainfalls for the years 1986-2008 from Zielonka meteorological station (data of Faculty of Forestry). The trend line is marked with a dashed line

According to the classification of Polish forest habitat types the research area represents the type of alder forest. The soil is composed of shallow organic layer (25-38 cm), underlain by a layer of sand. The ground water table is variable. After snowy winters or years with plenty rainfalls research area forms a shallow water reservoir. After dry period the water disappeared several dozen centimetres below the surface of the ground (Figs. 4a and 4b).

Table 1. Soil parameters

Soil horizon		AOM	D1gg	D2gg
Depth [cm]		0-25(38)	48	80
pH	H ₂ O	5.58	9.2	8.65
	KCl	4.8	8.18	8.11
C	[%]	2.51		
SOM	[%]	4.33		
N total	[%]	1.52		
NH ₄	[%]	0.06		
C:N		1.65		
Hygroscopic water	[%]	18.66		

For the purpose of the long-term observation of the activity of individual trees depending on changes in temperature and humidity of the air, as well as changes the level of groundwater, Department of Forest Sites and Ecology (Poznań University of Life Sciences, Faculty of Forestry) has constructed a set of sensors (ConTeH) which automatically register the tree conductivity (Con), temperature (Te) and humidity (H) at an assumed time interval and has placed - after long tests - the sensors in alder trees in natural conditions. First set of sensors was placed on November 2017, next ten on January 2019. This paper presents the results of measurements for the first set of sensors. All sensors are placed at the height of 2.0 m above ground, on the northern site of tree trunks to avoid the direct solar radiation. The method of embedding sensors on the tree is shown in Fig.3.

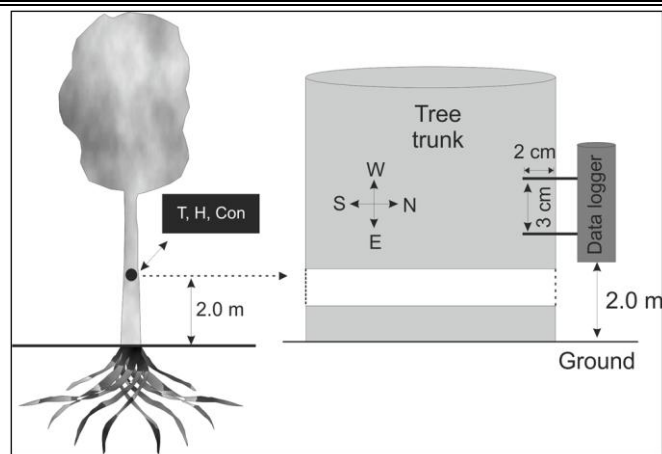


Fig. 3. The method of embedding device on the tree. The height of tree is 21.4 m, the perimeter 98 cm at the height of 1.3 m above ground (on April 2018)



Fig. 4a (left) and Fig. 4b (right). Tested alder forest (4a - phot. W. Krzyńska; April, 2018; 4b - phot. M. Konatowska; July 2019)

The ground water table was measured in piezometer every 3 weeks, since November 2017 to present

3. Results and discussion

The Fig. 5 shows the correlation between changes of ground water table and tree conductivity in choosing period, for *Alnus glutinosa*, growing in Zielonka Experimental Forest (Poznań University of Life Sciences, Poland) on mineral-muck soil.

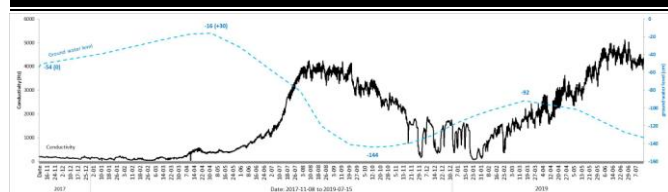


Fig. 5. Changes in conductivity in an alder tree and the groundwater table measured at the edge of an alder forest between November 11, 2017 to July 15, 2019

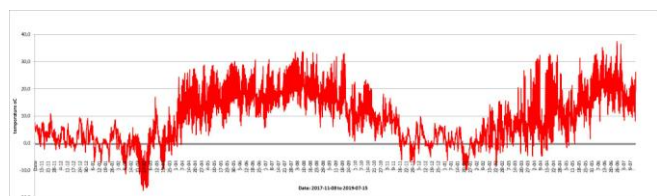


Fig. 6. Changes in the air temperature for the period shown in Fig.

5

The results obtained, shown graphically in Fig. 5 indicate the following:

1. There is a significant difference in the soil moisture condition of the tested alder in 2018 and 2019. In 2018, the maximum occurrence of groundwater in the piezometer was -16 cm, in 2019 -92 cm. In 2018, the maximum state of waterlogging was recorded on May 2, in 2019 on March 16. On May 2, 2019, the water was already at a depth of 102 cm, so 86 cm lower than in 2018. According to the Polish classification of forest habitats, the water maintained at a depth of 90 cm indicates a swampy habitat. If the water level drops below the depth of 90 cm, the habitat should be classified as wet, and this should entail a change in the species composition of the stand. The conducted research shows that natural changes in the alder forest moisture content exceed the range of 90 cm.
2. There was also a significant difference in the activity of the tree, expressed in its conductivity. In the winter of 2017/2018, the tested alder showed a long-lasting dormancy, from which the tree began to wake up at the turn of March and April. In the winter of 2018/2019, there were almost no resting periods. Short moment of dormancy was recorded on 20-25 January only, when the air temperature dropped below -6 °C, reaching the lowest values recorded in winter 2018/2019 on January 23 (-9.8 °C). From the turn of January and February 2019, the activity of the alder has already increased markedly (and 2 months earlier than 2018). The fact that in the winter of 2017/2018 the air temperatures were significantly lower (at least -17.4 °C on February 27) and the duration of low temperatures was longer and took place later (period with temperatures falling in the range from -6 to -17.4 °C lasted from February 22 to March 5). It should be noted, however, that the long period of dormancy of the alder in 2018 could also have been affected by the long-term persistence of high water level, inhibiting the development of trees. Although in the winter of 2017/2018 the air temperatures were lower and the temperature period below -6 °C occurred later, but in 2019 the frosts ended later. Despite the frost, the activity of the alder in 2019 was, however, high, which may indicate that the long state of dormancy of the alder in 2018 could also be affected by the high water level.

Perennial plants, such as trees, distinguish themselves from other plants in their ability to suspend and resume growth recurrently in response to environmental, and often seasonal, conditions [15]. Temperate climates are defined by distinct temperature seasonality with large and often unpredictable weather during any of the four seasons. To thrive in such climates, trees have to withstand a cold winter and the stochastic occurrence of freeze events during any time of the year [16]. This is well illustrated by the results of the conducted research, for which the data on air temperature measured in the shadow, 2.0 m above the ground, are presented in Tab. 2.

Table 2. Comparison of selected parameters in 2018 and 2019

Data for the period between 2018-01-01-00:25 a.m. and 2019-07-14-11:25 p.m.	2018	2019 (01-01 to 07-14)
	Value (°C)/ Month-Day/Hour:Minutes	
	2018	2019
Maximum temperature	+30.8/ 07-5/2:25 p.m.	+37.5/ 06-26/2:25 p.m.
Minimum temperature	-17.4/ 02-27/6:25 a.m.	-9.8/ 01-24/5:25 a.m.
Average temperature	8.2	9.2
Last spring frost	-0.2/ 04-7/ 3:25 a.m.	-0.3/ 05-14/ 4:25 a.m.

In phenological studies, the most difficult to assess the condition of a tree may be "dormancy period during winter". Vitasse et al. [16] provide a clear definition of this period, describing it as "leafless in deciduous trees", but in tree research dormancy is most frequently referred to as absence of visible growth in any plant structure containing a meristem [15]. Lang [17] distinguished three types of dormancy: ecodormancy, provoked by limitations in environmental factors; paradormancy, where the growth inhibition arises from another part of the plant; and endodormancy, where the inhibition resides in the dormant structure itself. In the research presented in this work, the measurement of conductivity in the tested alder in the leafless period can be related to the ecodormancy, which was influenced by the air temperature, but it cannot be excluded that in 2018 it could also have been affected by the state of long-term flooding which inhibited the development trees. Undoubtedly, the periods considered as dormancy period, in 2018 and 2019 in the activity of the tested alder were definitely different but it does not seem that the air temperature factor is the only one that plays role here.

As the results of pilot studies are presented in the paper, the authors are cautious in drawing unambiguous conclusions in this respect. Especially that the results presented concern only one tree. The authors are also aware that there are differences in the timing of phenology even between trees growing in close proximity to each other, depending on both individual and biosocial factors. Therefore, in 2019, the research was extended to another 10 trees, on the same research area, the conclusions of which can be drawn in the future. Then, taking into account the hydrological changes in the long-term cycle, taking into account the differences between trees in their features and phenology, it will be possible to more clearly determine both the impact of individual environmental factors and the consequences of the impact of these factors on individual trees. The mechanism of dependence between tree's conductivity and its condition, which can be affected by significant alder forest moisture changes in the short-term cycle as well as the long-term cycle, is not known.

4. Conclusions

Environmental factors, including temperature and air humidity, undoubtedly affect the life processes of plants, but in the black alder an additional factor responsible for the tree activity is the seasonal variability of soil moisture. In the conducted research, the activity of the tree, expressed as the conductivity measured in Hz, was seven times lower, in the period when the water level in 2018 was

high, than in the analogous period in 2019, when the level of groundwater was low. In the period from January 1 to May 31, 2018, the maximum value of conductivity reached 601 Hz, while in the analogous period of 2019, 4229 Hz.

Differences in the soil moisture also affected the length of the dormancy period of the tree, which in the first observation season lasted from November 2017 to April 2018, while at the turn of 2018 and 2019, the tree activity stopped for just a few days when air temperature dropped on January 23, 2019 to -9.8 °C.

5. References

- [1] San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A. (Eds.), 2016. European Atlas of Forest Tree Species. *Publication Office of the European Union, Luxembourg*. ISBN: 978-92-79-52833-0. DOI: 10.2788/038466.
- [2] Braun, H.J. 1974 Rhythmus und Grösse von Wachstum, Wasserverbrauch und Produktivität des Wasserverbrauches bei Holzpflanzen. *Allg. Forst- und Jagd-Ztg.* 145 (5), 81–86.
- [3] Herbst, M., Eschenbach, C. and Kappen, L. 1999. Water use in neighbouring stands of beech (*Fagus sylvatica* L.) and black alder (*Alnus glutinosa* (L.) Gaertn.). *Ann. For. Sci.* 56, 107–120.
- [4] Fremstad, E. 1983 Role of black alder (*Alnus glutinosa*) in vegetation dynamics in West Norway. *Nord. J. Bot.* 3, 393–410.
- [5] Lhote, P. 1985 *Etude écologique des aulnes dans leur aire naturelle en France*. ENGREF – Franche-Comté, Besançon, France, p. 125
- [6] Mac Vean D. 1953. *Alnus glutinosa* (L.) Gaertn, *J.Ecol.*, 41, 447–466.
- [7] BDL 2019. Bank danych o lasach wg stanu na 2018.01.01. <https://www.bdl.lasy.gov.pl>.
- [8] SPHL 2004. Siedliskowe podstawy hodowli lasu. DGLP, Warszawa
- [9] Matuszkiewicz W. 2006. Przewodnik do oznaczania zbiorowisk roślinnych Polski. PWN, Warszawa. pp. 537.
- [10] IUL 2003. Instrukcja urządzania lasu. (2003 b). Cz. 2. Instrukcja wyróżniania i kartowania siedlisk leśnych. Załącznik do Zarządzenia nr 43 Dyrektora Generalnego Lasów Państwowych z dnia 18 kwietnia 2003 r. CILP, Warszawa: 1-118.
- [11] DeWald L.E. and Steiner K.C. 1986. Phenology, Height Increment, and Cold Tolerance of *Alnus glutinosa* Populations in a Common Environment. *Silvae Genetica* 35, 5-6: 205-211.
- [12] Piūra A., Kundrotas V. 2002. Genetic variation in adaptive traits and ecological sensitivity of black alder. *Baltic Forestry*, 8 (2): 8-22.
- [13] Turchina, T. A. (2019). Phenospectrum of Black Alder (*Alnus glutinosa* Gaertn.) Plants in Ecotopes of the Central Part of Steppe Zone of European Russia. *Arid ecosystems*, 9, 15-25. doi: 10.1134/S2079096119010104.
- [14] BULiGL 2014. Plan urządzenia lasu Nadleśnictwa Doświadczalnego Zielonka na okres od 1 stycznia 2014 r. do 31 grudnia 2023 r. mscr.
- [15] Rohde A, Bhalerao R. 2007. Plant dormancy in the perennial context Trends in Plant Science. DOI: 10.1016/j.tplants.2007.03.012.
- [16] Vitasse Y., Lenz A., Körner C. 2014. The interaction between freezing tolerance and phenology in temperate deciduous trees. *Frontiers in plant science*. doi: 10.3389/fpls.2014.00541.
- [17] Lang, G.A. 1987 Dormancy: a new universal terminology. *HortScience* 22, 817–820.

ACTIVATED CARBON OBTAINING FROM VARIOUS RAW MATERIAL / VIA CHEMICAL ACTIVATION FOR THE PURPOSE OF ENVIRONMENTAL PURIFICATION – OVERVIEW

Assist. Prof. Dr. Eng. Liliya Manoilova¹⁾, Assist. Prof. Dr. Eng. Kamelia Ruskova²⁾

¹⁾University of Chemical Technology and Metallurgy 8 Kl. Ohridski, 1756, Sofia, Bulgaria

²⁾Technical University of Sofia, 8 Kl. Ohridski, 1756, Sofia, Bulgaria

Email:lili_manoilova@abv.bg; kruskova@tu-sofia.bg

Abstract: The activated carbons are among the chemical products widely used in the industry and life. Thanks to their unique combination of adsorption and electric chemical properties related to their strongly developed specific surface, porous texture and chemical nature of the surface, they have not lost their attractiveness and application for more than 150 years. The use of various types of carbon adsorbents for solution discoloration, air deodorization, for medical and cosmetic purposes, has been known for centuries. Their appearance happens to be the natural development of one of the most ancient technologies - for obtaining wooden coals and is based on the increase of the public consumption.

Keywords: ACTIVATED CARBON, ADSORPTION, PURIFICATION, ADSORBENTS

1. Raw materials for the production of activated carbon

The potential designation of the carbons is determined by the raw material, type of manufacturing technology and production conditions. The appropriate type of impregnated carbon, due to its specificity, must be carefully selected, to ensure safe protection, depending on its designation.

The activated carbons can be divided into two groups: Powder and granular (particulate) carbon. The powder carbon is most often used for solution adsorption. The granulated activated carbon finds application mainly for adsorption of gases and vapors and therefore it is considered as gas and recuperation carbon. It finds application also in liquid environment, for water dechlorination, solution discoloration and component resolution.

It is known that the adsorption properties and parameters of the activated carbons can be successfully varied depending on the synthesis conditions - temperature, type of the activating agent, the ratio: Precursor - activating agent etc., but also the type and composition of the raw material used [1-2].

In terms of the raw material, an essential advantage of the activated carbons is the fact that they can be obtained practically from any carbon containing raw material. Depending on the composition of the raw material, some of the most often used raw materials for obtaining activated carbon are bituminous coals, bones, coconut shells, peach, apricot, olive pits, apricot shells, petrol residues, wood and waste biomass from the agriculture, asphalt, metal carbides, soot, worn out car tyres, incineration products, synthetic polymers, wastes from the paper - cellulose industry, etc. [3-6]. The main parameters allowing suitable selection of activated carbon for certain purposes appear to be: the textural parameters - specific surface, total volume of the pores, the volume of the meso- and micropores as well as the ratio between them; the chemical nature of the surface (the presence of functional oxygen groups, the isoelectric point, pH of the water suspension of coals); the particle size composition (dispersion); the mechanical parameters (for instance the friability) etc.

The micro- and super-micro- pores, the determining size of which (>2 nm) is commensurable to the sizes of the adsorbing molecules, are of significant importance for the activated carbon.

2. Applications of the activated carbons

For decades now, the activated carbon finds application as an adsorbent, catalyst and/or carrier for catalysts in various areas such as medicine, food industry, chemical engineering, environmental preservation and above all in the gas-mask equipment as a means for individual protection from vapors of highly toxic substances [7].

The activated carbons have been used quite successfully for many years for adsorption and removal of impurities of processed gases and waters. They are the foundation of resolution of many problems of the recuperation of valuable components as well as the environment and human health preservation from hazardous air, water and soil pollutants [8]. They find wide application for purification of river and lake waters as well as waters transported to large distance through water pipeworks, from smell and unpleasant (swamp) taste. For instance, the water sterilized through chlorination is passed through adsorbents with granulated activated carbon or contacted with powder activated carbon whereat the unreacted chlorine and the formed chlorination compounds are separated (some of the chlorine organic compounds are very carcinogenic).

The activated carbon is used as a catalytic carrier of various active phases [5;9]. The activated carbons impregnated [10-11] with suitable phase (compounds of Cu, Cr, Zn, Mo, Ag, as well as with pyridine or triethen diamine –TEDA) are as of the moment non-alternative active materials for gas mask protection [12].

The requirement is for suitable mechanical and particle size parameters and above all suitable textural parameters such as specific surface, external and internal surface, specific surface of the mesopores, suitable distribution of the mesopores, mesoporous or macromesoporous type of activated carbon, with minimal volume of the micropores (preferably supermicropores). By rule, carbons are used of low ash content or prior to the impregnation with the phase, the inorganic substances are removed via acid treatment (for instance with HF).

In the quality of catalyst for hydration, powder activated carbon is often used impregnated with Palladium. The activated carbons impregnated with zinc acetate, are used to obtain vinyl acetate by the reaction of interaction of the acetylene with acetic acid. The activated carbons impregnated with mercury chloride are used as catalysts for obtaining vinyl chloride from acetylene and HCl. The activated carbons impregnated with alkaline silicates and

phosphates are used in the dehydrochlorination of the ethyl chloride to vinyl chloride.

3. Main methods for obtaining activated carbons

The production of the activated carbons may run on two stage or one stage technology. In the two stage, the activation is preceded by carbonization as the activation itself is physical type (with steam gas mixture, CO_2 , some types of oxides such as NO_2 , etc.) [9].

In the one stage, regardless of the opportunity for physical activation, more often the raw material is subjected to chemical activation with activating agents of acid type (H_3PO_4), alkaline bases (KOH , NaOH) and salts such as ZnCl_2 and K_2CO_3 [4].

Considering the major competition on the world market for activated carbons, the various methods for obtaining chemically activated carbons are continuously improved and as of the moment, the data in this area are above all company secret [13].

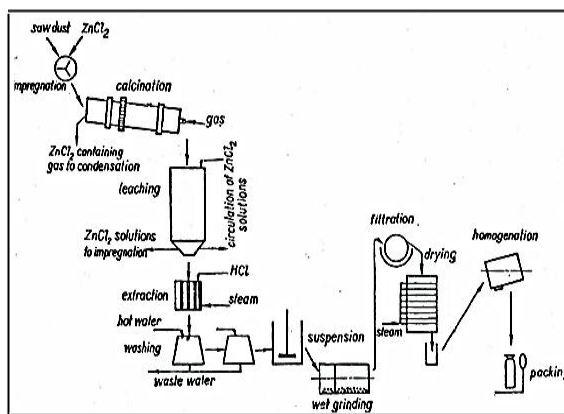


Figure 1. Technological chart of the production of powder activated carbon via zinc chlorination activation

3.1. Physical activation.

The main principle of obtaining activated carbon consists of the fact that the carbon containing material is subjected to preliminary selective thermal treatment with follow-up activation under the relevant conditions, as a result of which the specific surface increases and the porous texture develops.

During the activation of the carbon containing material, significant decrease of the mass of the solid substance takes place. Under suitable production conditions this results in equivalent increase of the porosity [14]. The part of the precursor (carbon containing material), which burns in the process of activation is called burn-off rate. The most important factor defining the capability of these materials to activate, appears to be the quantity of the volatile components [15].

Oxygen (air), water steam and carbon dioxide are usually used for physical activation [3;5;16]. This type of activation has a selective nature however in this case, a danger exists of non-controlled increase of the carbon burn-off, and therefore as activating agents, water steam and carbon dioxide are preferred.

The activated carbons with best characteristics are obtained at burn-off rate 50 %. At burn-off rate 50-75 %, heterogenous porous activated carbons are obtained with bidisperse micro-porosity and developed mesoporosity (micro-mesoporous activated carbons), whereat at burn-off rate higher than 75 %, the activated carbons are with strongly developed macro-porosity, the so called pre-activated activated carbons.

3.2. Chemical activation.

There is an impressive variety of references to chemical agents used for obtaining activated carbon [17]. For instance, the use of various carbonates or acetates in their quality of chemical agents which at high temperature emit oxidative effective gases of the type O_2 , CO_2 , etc., favor the formation of more homogeneous and strongly developed system of pores with various ratio of the micro- and mesopores. Publications are in place with data for chemical activation with potassium carbonate whereat the formation of porous structure has been reached at the expense of partial destruction of the carbon skeleton. Budinova and coauthors also use the potassium carbonate as an activating agent for obtaining activated carbon based on raw materials of vegetable origin and wastes from the production of antibiotics [17]. The authors prove that the activated carbons obtained this way possess a high adsorption capacity due to the presence of large amount of micropores and almost full absence of mesopores. There are data published also for the chemical activation of carbon containing raw materials via using nitric acid, hypochlorates, bichromates, etc. [18-19].

The chemical activation uses mainly non-carbonized starting materials such as peat, waste wood biomass [5;15;20]. Various waste slimes are currently used which, after the activation, are used as cheap sorbents for the purification of soils from heavy metals or for the purification of waters from the tailings ponds.

The transformation of the precursors referred in activated carbon runs under the impact of dehydrating agents at high temperature. In this case, the oxygen and hydrogen selectively and completely separate from the carbon containing material accompanied by carbonization and activation (usually at temperatures lower than 923K).

The woods, one of the most suitable for chemical activation carbon containing precursor, contains for instance about 49% oxygen and about 6% hydrogen, recalculated for dry and ash-free mass. The brown coals contain accordingly 25 and 5%.

In the capacity of activating agents, phosphoric acid, zinc dichloride, potassium sulphide are used in technology [5]. Besides, the following chemical substances can be used, possessing dehydrating effect – potassium rhodanide, sulphuric acid, etc. zinc dichloride [15] which as of the moment have not found any serious industrial application. Various combinations of chemical and/or chemical and physical activation are possible. If the activation at first takes place with ZnCl_2 , and then potassium carbonate is added, a product of high adsorption capability might result [20]. A combination of chemical activation with phosphoric acid and following activation with water steam, enriched with air is also an option [20]. The chemical activation in rotary furnace for 3 hours of a precursor, with phosphoric acid and zinc dichloride as activators enables the obtaining of formed product with competitive robustness to the carbons activated with water steam [5].

KOH takes a more special position as a chemical activator, as it has been proven that it “splits” the graffiti micro crystallites in layers among which the micropores are formed. Therefore, KOH is an effective activator also for the carbonized carbon containing materials [13;15;16]. Despite of the interest to the KOH activation, the literature lacks more detailed information about the “Amoco” technology for the production of activated carbons through it.

The method is relatively new and is considered as extremely perspective since it is in the foundation of all technologies for the production of activated carbons intended for “HighTech” products. It has been first introduced by the American company “Amoco” in a

product with the commercial signification AX-21 [21]. This is the activated carbon (industrial product with the highest specific surface, 2600 m²/g). Similar textural parameters are also displayed by another activated carbon – Maxsorb, of the Japanese KNCarbon Tech Co., Ltd (~ 3000 m²/g), designated for purification of halogenated carbohydrates of potable waters.

The most suitable precursors for the production of such activated carbons is considered to be the petrol coke but also coals, wood and lignocellulosic wastes, waste biomass of the agriculture.

Conclusion

The activated carbons appear to be extremely valuable industrial product whose production and assortment continuously expand. The modern trends in the technological development of the activated carbons are two – activated carbons with ultrahigh textural parameters and carbons based on the maximal utilization of the carbon containing industrial, agricultural and municipal wastes.

The above referred chemical activation enables the obtaining of activated carbons with very good parameters despite of the fact that the published materials for it are less compared to those for the steam gas activation; the interest to it nonetheless big.

References

1. Deitz, V.R., C.J.Karwacki, Chemisorption of cyano-containing vapors by metal-ligand structures adsorbed by activated carbon, Carbon (1994) Vol.32 N° 4 .
2. Davies, G.M., N.A. Seaton, The effect of the choice of pore model on the characterization on the internal structure size distribution. Carbon Vol. 36 (1998).
3. Lavanchy, A., F.Stoeckli, Dinamic adsorption, in active carbon beds, of vapor mixtures coresponding to miscible and immiscible liquids, Carbon Vol. 36 (1998).
4. Choma, J., M. Kloske, "Otrzymywanie i wlasciwosci impregnowanych wegli aktywnych," Ochrona Srodowiska, (1999) vol. 2, no. 17, pp. 3-17,
5. Кинле, Х., Е. Бадер, „Активные угли и их промышленное применение”, Изд. „Химия”, Ленинград, 1984.
6. Mattson, J., H. Mark Jr., “Activated Carbon”, Marcel Dekker, NY (1971).
- 7.Тончев И., „Изследване върху основните характеристики на енергийно гориво от Чукуровския и Софийския лигнитни басейни”, Хабилитационен труд, София, 1973 г.
8. Родионов, А., В. Клушин, Н. Торочешников, „Техника защиты окружающей среды” Изд. „Химия”, Москва, 1989.
9. Величкова Н., Дисертация, БАН, София, 2004.
10. Manoilova L., A. Chatzis, Iv. Spassova Iv., R. Nickolov ; Concept for the development of a new type carbon catalyst designed for protection against vapours of highly tohic substances, Machines, Technologies, Materials ”, IX, issue 5, Veliko Tarnovo (2015) 27-29
11. Manoilova, L., A. Chatzis, D.Vladov, Iv. Spassova , R. Nikolov; Effect of additives in phase composition of carbon catalysts other than ASC Whetlerite type carbons on their removal efficiency against hydrogen cyanide vapors in the air , Science. Business. Society. 5/2016
12. Николов, Р., Дисертация, ВТНИИ, София, 1988.
13. Viswanathan B., P. Indra Neeland, T.K. Vatadarajan, Methods of activation and specific applications of carbonmaterials, National Centre for Catalysis Research, Department of Chemistry, Indian Institute of Technology, Madras, 2009.
14. Bansal P. Ch., Donnet J.-B., F. Stoeckli, Active Carbon, Marcell Dekker, N.J., 1988
15. Плаченев Т.Г., Технология сорбентов. Активированные угли, Ленинград, Госхимиздат, 1941.
16. Фенелонов В. Б., Пористый углерод, Институт Катализа, СО РАН, Новосибирск, 1995.
17. Budinova, T., N. Petrov, J. Parra, V. Baloutzov, Use of an activated carbon from antibiotic waste for the removal of Hg(II) from aqueous solution, Journal of Environmental Management 88 (2008), 165–172
18. Vinke, P., M. van der Eijk, M. Verbree, A.F.Voskamp, Modification of the surface of a gas-activated carbon and a chemically activated carbon with nitric acid, hypohlorite, and ammonia, Carbon Vol. 32 N° 4 (1993).
19. Evans, M.J.B., E. Halliop, S. Liang, J.A.F. Mac Donald, The effect chlorination on surface properties of activated carbon, Carbon 36 (1998).
20. Кельцев Н.В., Основы адсорбционной техники, Москва, Химия, 1976.
21. www.chemicalsafetyconsulting.com, "Material Safety Data Sheet: Specifying Respiratory Filter Type" (2013).

THE RESEARCH OF THE RAIN INTENSITY ADAPTATION TO THE CONDITIONS OF HYDROPHYSICAL CHARACTERISTICS OF THE SOIL FOR ECOLOGICAL AND ECONOMICAL IMPROVEMENT OF THE IRRIGATIVE EQUIPMENT

Iu. Melnic, A. Coronovschi, R. Ceban, A. Melnic.
State Agrarian University of Moldova, Chisinau, Republic of Moldova,
iu.melnic@uasm.md, a.coronovschi@uasm.md

Abstract: The article presents the result of the research on the possibility of using in the watering process the effect of swallowing and cracking of chernozem soils depending on their humidity. Watering installations where the rain intensity is variable or constant but higher than $K_f = \text{const}$ lead to an essential reduction of working time in position, since in this case the soil soaking process also includes the infiltration phase.

Water losses would be less because in this case the soil soaking process also includes the infiltration phase in which, depending on its initial humidity, the soil can incorporate essential water volumes. Consequently, it is possible to improve the ecological and economic efficiency of the irrigation technique by adapting the intensity of the rain to the dynamics of the process of water movement in the soil during the watering process.

KEYWORDS: SOIL WATER FIELD CAPACITY (CC), THE MOVEMENT OF WATER IN THE SOIL, EFFECT OF SOIL SWELLING.

1. Introduction

It is known that while choosing the irrigative equipment, one of the most important and decisive factor is that of the rain intensity produced by the installation. This intensity must definitely be smaller or equal to the speed of the water circulation of soil with the humidity of CC (field capacity).

Taking into account the fact that black earth (chernozem's soil) has the speed of filtration about 0.3-0.5mm per minute, watering norm of 55mm can be absorbed in soil in about 3-4 hours, which makes a disadvantage the usage of the irrigative equipment.

Another problem while irrigating appears due to the small level of the homogeneity of the soil's type or sub-type spread in the area that is irrigated. Because of this from time to time may happen some losses of water by its leak from the surface and by percolations on the soil.

In turn, these phenomena lead to the leakage of organic, mineral and chemical leaching substances, thus producing a negative impact on the fertility of the irrigated soil and the environment.

Considering these, the goal of the research is the demonstration of the possibility of the irrigation equipment's modernization in conditions of the increasing

of rain intensity. So that the its intensity would fit in the limits:

$$K_{fmax} > I > K_{fCC}. \quad (1)$$

where: K_{fmax} – the speed of the water circulation after the first hour of the research of the permeability of soil for water;

K_{fCC} – the speed of water circulation when the soil's humidity is equal to CC.

The research was made on the base of the existing and personal studies of the irrigation water circulation and distribution in soil.

2. Results and discussions

As we already mentioned, technical characteristics of the irrigation equipment are chosen depending on the speed of the water filtration on soil with the humidity equal to CC (Fig.1).

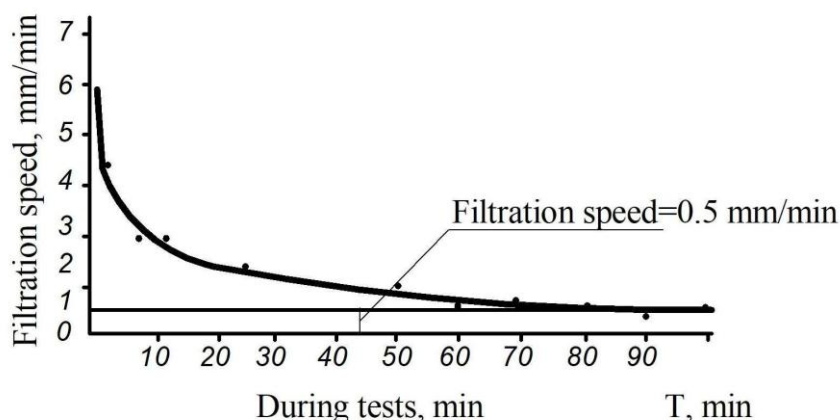


Fig.1. Choosing the intensity of rain

As we see in this figure, the speed of the filtration is about 0.5mm/min. Considering this, actually, the intensity of the artificial rain made by the irrigation equipment does not have to overcome this level (0.5mm/min). This, as was already mentioned, is an accepted condition with the goal of not permitting leaking on the surface.

Coming out of this condition one can calculate the time of the functioning of any irrigation machine: the smaller is the speed of water circulation, the longer is the time of the positioning. With all this, there appear relatively big losses of the irrigation water both due to the leaking on the surface and to the percolations on the soil [1].

These phenomena happens because the pedological conditions of irrigated areas are not homogeneous. That means that in the area of one type or sub-type can exist even 1% of some other types of soil

which have different hydrophysical characteristics. That is why if the irrigation equipment was chosen for one type of soil with one speed of the water filtration with the humidity CC, then when we meet sub-areas of other types and sub-types of soil with worse hydrophysical characteristics, only then in these conditions the negative impact can be essential (losses of about 35% absorbed water) [1, 2].

Apart from this, the actual concept of the movement and distribution of water in the unsaturated with water soil is based on the idea that the water that penetrates the soil, firstly saturates all the pores and particles of one certain layer in a hygroscopic and capillary way [2, 3].

The water that is influenced by the force of gravity enters gradually in the depth of soil, moisturizing continually the soil until the level of depth where its saturation becomes complete with this

hygroscopic and capillary water. It turns out that every layer of soil becomes similar to an accumulating container which fills itself with water, and the excessive quantity of water runs out into the container situated below.

That is why the traditional physico-chemical approach of water movement into the soil frequently leads to a negative impact on this soil.

Ecological consequences can be highly unpredictable: sodiumisation, consolidation of soil masses and cessation of transformation of organic material into humus [4, 5, 6, 7]; the raising of phreatic water level over the critical limits, the periodic apparition of anaerobic processes [7]; the losses of structure, compaction, hydrophilisation of mineral colloids, secondary gleization [8]; the leaching of carbonates and of nutrients, the increasing of Na^+ and Mg^{2+} content of microbial restructuring

[7, 9].

One of the reasons why these problems appear is the soil's maintaining of some regimes of humidity not appropriate for hydrophysical characteristics of the chernozem.

In order to change these problems' state the accommodation of humidity regimes of soil to its hydrophysical natural properties is strongly required.

In order to remove the mentioned disadvantages we offer the modernization of the irrigation equipment by usage of hydrophysical characteristics of black earth to inflate in the contact with water. In the result of the inflation in time, the speed of the water circulation is modified from the maximum in the initial phase to the minimum in the phase when the soil is imbued wholly with water (Fig.2).

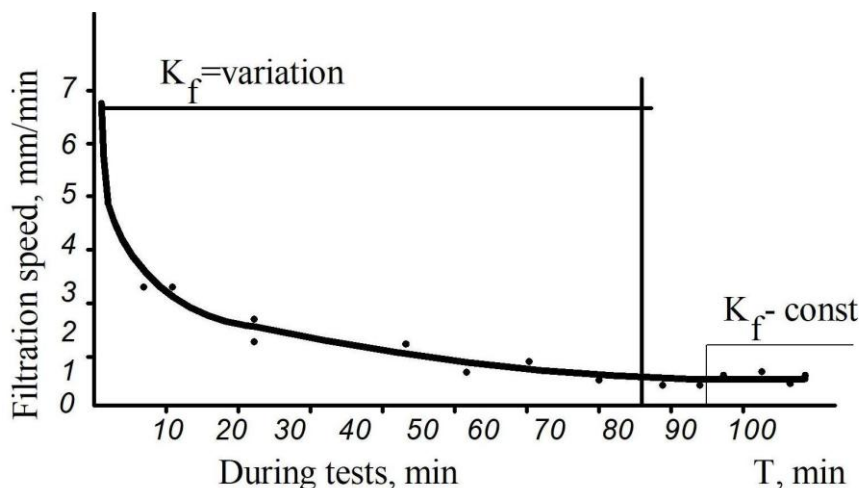


Fig.2. Dynamic intensity of water irrigation:

K_f = variation and K_f = const - coefficients of water infiltration into the soil (variable and constant).

From the graphic we can observe that while absorbing of the water into the soil not saturated initially with water, the process of water circulation happens in two phases:

1. Soaking of soil with water by filling the blanks (infiltration through the unsaturated soil with water in the process of the inflation).
2. Filtration. A phase when the water moves through the soil in the inflated state and completely imbued with water).

In the first phase, due to the fact that the soil is not inflated, the speed of the water circulation is relatively fast (0.5-5.8mm/min), while in the second phase the speed is relatively constant (about 0.5 mm/min) because the soil was made compact.

In order to use this characteristic of the chernozem we need to equip the irrigation technique with the possibility of changing of the produced rain intensity depending on the specific dynamics and characteristics of water circulation in the irrigated soil (Fig.2).

Example. The soil administers some norm of the humidity of 550 m^3/ha , in case of usage of the specific character of the humidity circulation in soil in the first phase, the functioning time of positioning would vary from 9.5 to the 110 min. In the second case this time would be minimum 110 minutes.

As can be seen, the average time required to administer the of 550 m^3/ha with the new method would be twice as fast as when using the real method.

Conclusions:

1. Irrigation with the instalations which have the variable or constant but higher then the K_f = const intensity of rain (shower) lead to the essential reduction of working time because in this case the process of the soil wetting includes the phase of infiltration.
2. Water losses could be less essential because in this case the process of soil wetting includes the phase of infiltration, a phase

when, depending on the its initial humidity, the soil can incorporate essential volumes os water (Fig.2).

References:

1. Coronovschi A., Ceban R.. Perfecționarea metodei de stabilire a regimului de umiditate a solului la irigare. Agricultural science, 2016, nr.2. - Chișinău: State Agrarian University of Moldova, pp.111-116, ISSN 1857-0003(print), ISSN 2587-3202(electronic). <http://www.uasm.md/ro/stiintaagricola>
2. Болокан Н. Воздействие с/х культур и агротехнических приемов на водопроницаемость почвы. - Кишинев: Штиинца, 1986, 147 стр.
3. Melnic Iu., Melnic Angela. Calculul parametrilor constructivi ai paletelor pentru creșterea răsădului. Intellectus, 2008, nr.1. - Chișinău: AGEPI, 2008. - pp.12-14, 0,35 c.a., ISSN 1810 7079.
4. Крупеников И.А., Подымов Б.П., Скрябина Э.Е. Влияние орошения на свойства и плодородие почв. Обзорная информация. - Кишинев: Молд. НИИТИ, 1985. - 60 с.
5. Sinkevič, Z.A., Ganenko, V.P. Vlianie irigacii na sovremennye processy v černozeme obyknovennom.// Černozemy Moldavii i ih racional'noe ispol'zovanie: tezis doklada konferencii. - Kišinev: Știinca, 1983. - pp.51-53.
6. Ковда Б. Научные и практические проблемы мелиорации почв. Почвоведение, №2. - Москва, 1979, стр.5-17.
7. Синкевич З.А. Современные процессы в черноземах Молдавии. - Кишинев: Штиинца, 1989. - 214 с.
8. Подымов Б.П., Скрябина Э.Е. Оглинивание как диагностический признак орошаемых черноземов. // Почвы Молдавии и их использование в условиях интенсивного земледелия. - Кишинев: Cartea moldovenească., 1978. - pp.192-194.
9. Аниканова Е.М. и др. Основные проблемы орошения черноземов юга Европейской части СССР. //Сборник трудов: Проблемы ирригации почв юга черноземной зоны. - М.: Колос,1980. - С.5-11.

OPPORTUNITIES FOR AGROFORESTRY IN LATVIA

Mg. chem. Bardule A., Dr. silv. Lazdina D., Mg. oec. Makovskis K., Dr. silv. Bardulis A.
 Latvian State Forest Research Institute "Silava", Rīgas Str. 111, Salaspils, LV-2169, Latvia
 E-mail: arta.bardule@silava.lv

Abstract. Agroforestry has the potential to provide a broad range of ecosystem services including maintenance and improvement of soil and water quality. Nevertheless, there is a lack of supporting policies both at national and at European level. Moreover, although tree cover density on agricultural land is surprisingly high in the Baltic States, agroforestry is seldom immediately associated with boreal and hemiboreal regions. Two agroforestry systems corresponding best to the farming traditions in Latvia are short rotation coppices grown on agricultural land and silvopastoral systems. In Latvia, the first experimental area of agroforestry systems of fast growing tree species (*Populus* spp., *Salix* spp. etc.) and legumes or perennial grasses was established in 2011. To promote the implementation of bioeconomy principles, municipal waste (wastewater sludge) and renewable energy by-products (wood ash and digestate) were applied as fertilizers to promote increase of yield. Within the study, not only benefits of agroforestry systems were evaluated but also ecological risks associated with the application of fertilizers.

KEYWORDS: AGROFORESTRY SYSTEMS, APPLICATION OF FERTILIZERS, HEMIBOREAL REGION, HYBRID ASPEN

1. Introduction

During the recent years, there has been a surge of concern and attention to processes of soil degradation and deterioration of water quality that have negative impacts on human health, natural ecosystems and climate, as well as on economy. Protection of soil fertility and water resources is therefore one of the cornerstones of environmental protection in Europe. Soil and water quality issues transcend national boundaries, and concerted action at the level of the EU and even at the global level is necessary to ensure effective protection (The European Commission, 2019).

Agroforestry, defined as land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence, can be used to mitigate the mentioned threats. In agroforestry systems there are both ecological and economical interactions between the different components. Agroforestry can also be defined as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (FAO, 2019). Agroforestry systems range from subsistence livestock and pastoral systems to home gardens, alley intercropping, and biomass plantations with a wide diversity of biophysical conditions and socio-ecological characteristics (Zomer et al., 2009).

Agroforestry systems can provide a wide range of ecosystem services, including supporting services (e.g. pollination and carbon cycling); regulating services (e.g. protection against wind, biological pest control and nitrogen fixation); and provisioning services (e.g. food and non-food products for home consumption and income generation) (Hillbrand et al., 2017). Moreover, agroforestry, as a sustainable land management practice, has shown solid evidence of its role in improving soil and water quality based on at least four decades of data gathered from the world over (Dollinger & Jose, 2018). Perennial woody tree species are important components of agroforestry system. They have extensive root systems and accumulate large quantity of biomass (above and below ground) as compared to annual crops. Agroforestry has the ability to (1) enrich soil organic carbon better than monocropping systems, (2) improve soil nutrient availability and soil fertility due to the presence of trees in the system (litter addition, decomposition and nutrient release, biological nitrogen fixing), (3) enhance soil microbial dynamics (increase diversity and density of macroinvertebrates in the soils), which would positively influence soil health and play an important role in ecological processes such as breakdown and cycling of organic matter (Dollinger and Jose, 2018; Pinho et al., 2012), (4) pump nutrient and control erosion losses that are vital processes for improving soil nutrient status for sustainable farm production (Sarvade et al., 2014), (5) reduce water consumption, help retain water for crops and provide protection to watersheds (World Agroforestry, 2019).

Agroforestry systems are currently more common in temperate, sub-tropical and tropical zones, and include a wide range of land uses and practices (Feliciano et al., 2018). In the boreal and hemiboreal regions, agroforestry is not practiced on a wide scale (Lovrić et al., 2017). In Northern Europe, farmers identified that the key benefits of agroforestry are primarily social and environmental, rather than economic (Graves et al. 2009). The profitability of agroforestry in the boreal region is constrained because such systems are not eligible for financial support (Lovrić et al., 2017).

In Latvia, there is a long tradition of several agroforestry systems such as silvopasture, clusters of trees in arable land (silvoarable), riparian buffer strips, hedgerows and windbreaks etc., but agroforestry is not defined by national legislation in Latvia. There are two main farming methods which could be classified as agroforestry - short rotation coppices (SRC; trees are grown on agriculture land and are being managed like agriculture crops; Picture 1); and silvopastoral systems (Picture 2). If less than 50 single trees or trees in small clusters are growing on the field it is eligible for common agriculture payments and could be classified as normal agriculture practice, otherwise only SRC systems planted outside ameliorated areas are eligible for payments. In 2018 in Latvia there were 220 ha of *Populus* spp., 442 ha of *Salix* spp. and only 3 ha of *Alnus incana* with the status of short rotation coppice. Furthermore, it is becoming popular to cooperate between willow farmers and beekeepers because there are plenty of meadow species below the canopies in SRC, besides that, willows are the first plants blooming in the spring (Pučka et al., 2016; Pučka & Lazdiņa, 2017; Krēsliņa et al., 2017; Lazdiņa & Bardulis, 2019). There are no available statistics on how many ha of forest and bush land are used for grazing. In Latvia, there is a huge potential for human made silvopastoral systems where fast growing coppice trees (common for SRC systems) can be used for shelter of cattle to improve the keeping conditions (providing windbreaks and shading). Shelter trees are becoming more important in terms of climate change as well – due to extreme weather conditions and as capturers of CO₂ (Lazdiņa & Bardulis, 2019).



Picture 1. Two years old hybrid aspen (*Populus tremuloides* Michx. x *Populus tremula* L.) plantation in agricultural land in Latvia



Picture 2. Silvopastoral systems in Latvia - clusters of Scots pine (*Pinus sylvestris* L.) in pasture of calves

2. Impact of agroforestry system of hybrid aspen and perennial grasses or legume on soil and water quality

2.1. Research object

Research was carried out in the central part of Latvia (in Skrīveri district, 56°41' N and 25°08' E). The research object was established on agricultural land in spring 2011. The experimental plot of hybrid aspen (*Populus tremuloides* Michx. x *Populus tremula* L.) is a part of a large-scale multifunctional plantation of short rotation energy crops and deciduous trees with a total area of 16 ha. Soil types according to the World reference base for soil resources (2006) is Luvic Stagnic Phaeozem, Hypoalbic and Mollic Stagnosol, Ruptic, Calcaric, Endosiltic, the dominant class of soil texture is loam and sandy loam at 0-20 cm depth and sandy loam at 20-80 cm deep.

Two different clones (No. 4 and No. 28) of one year old container seedlings of hybrid aspen were planted in agroforestry system (distance between trees 2.5 x 5.0 m) and as tree plantation (distance between trees 2.0 x 2.0 m). Plant material producer - JSC "Latvia's State Forests" nursery "Kalsnava", Latvia. In sample plots established in the agroforestry system, between the 5 m tree rows, two legume (*Galega orientalis* Lam. "Gale" and *Lupinus polyphyllus* L. "Valfrid") and two perennial grass (*Phalaris arundinacea* L. "Bamse" and *Festulolium pabulare* "Felina") cultivars were sown for seed production. The grasses and the legumes were placed in 2.5 m wide columns. A free space of 1.25 m between the trees and grass lines was provided.

Wastewater sludge, stabilized wood ash and bio-gas production residue digestate were initially applied as nutrient and soil buffer capacity compensatory fertilizers to improve soil quality (Table 1). Wood ash and wastewater sludge fertilizers were applied shortly before the planting of hybrid aspen in spring 2011, but digestate was applied immediately after planting of the hybrid aspen seedlings. In addition, control plots were established where no fertilizers were applied.

In the research object (Picture 3), soil (0-80 cm depth) and soil solution (at 30 and 60 cm depth) sampling and physical and chemical analyses were performed during the study period from 2011 to 2015.

Table 1. Characteristics of used fertilizers

Fertilizer	Dose	Type of distribution	Input of nutrients through fertilization, kg ha ⁻¹		
			total N	total P	total K
Stabilized wood ash	6 t DM ha ⁻¹	mechanically	2.6	65	190
Digestate	30 t ha ⁻¹	point source	69	1.2	99
Wastewater sludge	10 t DM ha ⁻¹	mechanically	259	163	22



Picture 3. Research object in Latvia

2.2. Results and discussion

Soil quality

Soil bulk density is an important physical parameter for soil nutrient storage, water retention capacity and gas exchange in soils or soil aeration (Wang et al., 2011). In research object, we found statistically significant decrease in average soil bulk density at 0-40 cm depth in 2015 if compared to 2011. It demonstrates that tree growth and development of root systems decrease the soil bulk density in the upper soil layers and soil becomes more permeable to water and gaseous substances, while the impact of tree growth on soil bulk density in the deeper soil layers is negligible.

Soil pH is one of the most important parameters affecting soil biological activity, plant growth, as well as ion exchange capacity, solubility of organic substance and minerals, nutrient availability to plants and losses of nutrients due to leaching (Nikodemus et al., 2008; Lutter et al., 2016a). Considering the large natural variation of soil acidity in the research object, statistically significant differences in soil acidity between control and treated plots were found only in several plots where wastewater sludge or wood ash fertilizers had been initially applied. Statistically significant changes in soil acidity due to establishment of plantation were not detected.

It is considered that agroforestry systems have a large carbon sequestration potential (Udawatta & Jose, 2011). In the research object, organic C content in soil at 0-20 cm depth ranged from 8.3 g kg⁻¹ to 38.3 g kg⁻¹ in 2011 and from 6.1 g kg⁻¹ to 47.0 g kg⁻¹ in 2015, but in deeper soil layers (at 60-80 cm depth) – from 0.06 g kg⁻¹ to 6.7 g kg⁻¹ in 2011 and from < 0.01 g kg⁻¹ to 12.4 g kg⁻¹ in 2015. Within the study, statistically significant differences in organic carbon stock between 2011 and 2015 were not detected, but, contrary to expectations, at 40-80 cm depth the organic carbon stock in soil in 2015 was significantly lower than in 2011. There is a heterogeneous soil composition in the research object due to recent soil recultivation – 20 years ago ground levelling and application of peat was done confirmed by the inclusions of organic matter in the soil profile (Bardule et al., 2013). Lower soil bulk density promotes better soil aeration and decomposition of soil organic matter. Thus, the reduction of soil organic C stock found within the study can be explained by the mineralization of peat applied 20 years ago.

Although in the boreal conditions the largest storage of ecosystem N is in soils and N cycling by foliage litter is very intensive, especially in plantations of fast growing deciduous trees (Meiresonne et al., 2006), changes in N stock in soil after afforestation of agricultural land have been significantly less studied than changes in organic C stock in the soil (Lutter et al., 2016b). Within the study both in 2011 and in 2015 statistically significant differences in total N content in soil were not detected between control and treated plots within the planting design. Average total N content in upper soil layers (0-20 cm depth) in the research object before hybrid aspen planting was 1.7 ± 0.1 g kg⁻¹, but after five vegetation seasons since establishment of plantation (in 2015) average total N content in upper soil layers had increased up to 1.9 ± 0.1 g kg⁻¹. Average total N stock in upper soil layers (0-20 cm depth) during the first five years after establishment of tree plantation in agricultural land had not changed (0.50 ± 0.03 kg m⁻²),

but average total N stock in 0-80 cm soil layer had decreased from $1.2 \pm 0.1 \text{ kg m}^{-2}$ in 2011 to $1.13 \pm 0.06 \text{ kg m}^{-2}$ in 2015.

So far, in boreal and hemiboreal region, only few studies are conducted to evaluate impact of establishment of plantation of fast growing *Populus* spp. on nutrient cycling in soils. Although it is considered that homogeneous topsoil is characteristic in agricultural lands (Lutter et al., 2016a), we found a relatively high variation in our study: for instance, in 2011 in upper soil layers (0-40 cm depth) in control plots nitrate content ranged up to $5.1 \text{ mg NO}_3^- \text{N kg}^{-1}$, ammonium ion content ranged from 3.2 to $20.7 \text{ mg NH}_4^+ \text{N kg}^{-1}$, phosphate content ranged from 46.3 to $190.8 \text{ mg PO}_4^{3-} \text{P kg}^{-1}$, but K content – from 31.2 to $176.2 \text{ mg K kg}^{-1}$. Due to comparatively large natural variation of nutrient content in the soil, significant increase in nutrient content was detected only in several plots where fertilizers had been initially applied. Similarly, during the first two years after establishment of hybrid aspen plantation in agricultural land and application of fertilizers significant decrease of nutrient content in soil was not detected, excluding several plots, but it did not indicate a clear trend of decrease of nutrient stock in soil.

Soils naturally contain a number of heavy metals, and many of them are important plant nutrients (Frausto da Silva & Williams, 2001). However, the largest amount of heavy metals in soil are the result of pollution and are toxic (Smidt et al., 2012). Considering the large natural variation of heavy metal content in soil in the research object, statistically significant differences of heavy metal content in soil between control and treated plots were not detected. Consequently, no significant deterioration of soil quality in the context of contamination with heavy metals has been observed as a result of application of fertilizers, although target values of Zn, Ni, As and Cd content in the soil for achieving sustainable soil quality were exceeded both in the topsoil and in deeper soil layers.

Soil solution quality

Agroforestry systems are considered as an approach for reduction of diffuse pollution in agricultural lands, moreover, agroforestry systems improve drainage quality with the reduction of rate of surface runoff, which contributes to infiltration, sediment deposition and nutrient retention. Moreover, in agroforestry systems, tree roots intensively take up nutrients, and thus the nutrient leaching into groundwater is reduced (Lee et al., 2003; Allen et al., 2004; Nair & Graetz, 2004; Jose, 2009).

Changes of pH can have a significant impact on nutrient cycling in tree ecosystems (Těrauda, 2008). Significant differences in soil solution pH between control plots (average soil solution pH was 7.68 ± 0.05) and treated plots (average soil solution pH was 7.85 ± 0.02) were not detected. However, in the period from 2012 to 2015 a lower average soil solution pH value (7.76 ± 0.02) was found if compared to the average pH value in soil solution in 2011 (8.35 ± 0.02).

During the filtration of water of atmospheric precipitation through the vegetation and soil layers, conductivity (amount of salts dissolved in the water) of the water increases significantly. In all plots, higher annual average soil solution conductivity was detected in 60 cm depth if compared to 30 cm depth, in several plots the difference was statistically significant. At the same time, comparing annual average values of soil solution conductivity in control and treated plots, significantly higher soil solution conductivity was detected in the plots where wood ash and wastewater sludge fertilizers had initially been applied.

Mitigation of leaching of nutrients is one of the ecosystem services provided by the agroforestry systems (Tully et al., 2012). The results of soil solution analysis indicate significant differences in nutrient content in soil solution at the beginning and end of the study period, as well as between plots where different fertilizers had been initially applied. In all plots, the highest $\text{NO}_3^- \text{N}$ content in soil solution in 60 cm depth was observed in 2011 and significant decrease of $\text{NO}_3^- \text{N}$ content in soil solution was observed over time (on average from $11 \pm 2 \text{ mg L}^{-1}$ in 2011 to $0.08 \pm 0.02 \text{ mg L}^{-1}$ in 2015). Comparing to control plots, in plots where wastewater sludge fertilizer had been initially applied significantly higher $\text{PO}_4^{3-} \text{P}$ content in soil solution in 60 cm depth was observed in 2014 and in 2015. Similarly, in 2014 and in 2015 significantly higher $\text{PO}_4^{3-} \text{P}$

content in soil solution in 60 cm depth was observed in plots where wastewater sludge fertilizer had been initially applied if compared to 2011 showing gradual decomposition of fertilizer's organic matter. This trend was observed in soil solution also in 30 cm depth. During the study period from 2011 to 2015 the highest average K content in soil solution in 60 cm depth was observed in plots where wood ash fertilizer had been initially applied showing significant impact of fertilizer on K concentration in soil solution. The highest K content (21.4 mg L^{-1}) in soil solution in 60 cm depth was observed in the beginning of summer 2012 in plot where wood ash fertilizer had been initially applied.

Heavy metal (Mn, Ni, Cu, Zn, As, Cd and Pb) content in water samples of soil solution and atmospheric precipitation sampled in spring of 2015 was evaluated – in the fourth year after application of fertilizers. During the filtration of water of atmospheric precipitation through the soil layers water was enriched with Ni, Cu, Pb and As, but in atmospheric precipitation higher Mn (except soil solution sampled in 60 cm depth in the plots where wood ash fertilizer had been initially applied), Zn and Cd content was observed if compared to heavy metal content in soil solution. Considering the large natural variation of heavy metal content in soil solution, we found no significantly higher heavy metal content in soil solution in plots where fertilizers had been initially applied.

4. Conclusions

The results from the analysis of five years' trends of soil and soil solution quality in fertilized juvenile hybrid aspen (*Populus tremuloides* Michx. x *Populus tremula* L.) plantation cultivated in an agroforestry system in hemi-boreal conditions demonstrate that establishment of agroforestry systems in agricultural land and the application of fertilizers from municipal waste (wastewater sludge) and renewable energy by-products (wood ash and digestate) can significantly affect soil and water quality in ecosystems. At the same time, this type of management serves the implementation and promotion of the circular bioeconomy.

5. Literature

- The European Commission, 2019. Available: http://ec.europa.eu/environment/index_en.htm.
- FAO, 2019. Available: <http://www.fao.org/forestry/agroforestry/80338/en/>.
- Zomer R.J., Trabucco A., Coe R., Place F. 2009. Trees on farm: analysis of global extent and geographical patterns of agroforestry. ICRAF Working Paper no. 89. Nairobi, Kenya: World Agroforestry Centre.
- Hillbrand A., Borelli S., Conigliaro M., Olivier A. 2017. Agroforestry for landscape restoration. Exploring the potential of agroforestry to enhance the sustainability and resilience of degraded landscapes. Food and Agriculture Organization of the United Nations, Rome, 28 p.
- Dollinger J., Jose S. 2018. Agroforestry for soil health. *Agroforestry Systems*, 92, 2, 213–219.
- Pinho R.C., Miller R.P., Alfaia S.S. 2012. Agroforestry and the improvement of soil fertility: A View from Amazonia. *Applied and Environmental Soil Science*, Article ID 616383, 11 p.
- Sarvade S., Singh R., Prasad H., Prasad D. 2014. Agroforestry practices for improving soil nutrient status. *Popular Kheti*, 2, 1, 60–64.
- World Agroforestry, 2019. Available: <http://www.worldagroforestry.org/news/agroforestry-water-wise-farming>
- Feliciano D., Ledo A., Hillier J., Nayak D.R. 2018. Which agroforestry options give the greatest soil and above ground carbon benefits in different world regions? *Agriculture, Ecosystems & Environment*, 254, 117–129.
- Lovrić M., den Herder M., Rois M., Graves A., Pisanelli A., Lovrić N., De Jalon S.G., Vityi A., Varga A., Burgess P. 2017. Application of analytic network process for five Europe's biogeographical regions. Environmental and socio-economic framework conditions of agroforestry in different regions in Europe. 38 p.

- Graves A., Burgess P., Liagre F., Pisanelli A., Paris P., Moreno G., Bellido M., Mayus M., Postma M., Schindler B., Mantzanas K., Papanastasis V.P., Dupraz C. 2009. Farmer perceptions of silvoarable systems in seven European countries. In: Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (eds) *Agroforestry in Europe. Advances in Agroforestry. Volume 6*. Springer.
- Lazdina D., Bardulis A. 2019. *Agroforestry practice in Latvia*. 4th World Congress on Agroforestry. 20-22 May 2019, Montpellier, France.
- Pučka, I., Lazdiņa, D., Bebre, I. 2016. Ground flora in plantations of three years old short rotation willow coppice. *Agronomy Research*, 14 (4), 1450-1466.
- Pučka I., Lazdiņa D. 2013. Review about investigations of *Salix* spp. in Europe. *Research for Rural Development*, 2, 13-19.
- Krēsliņa V., Štikāne K., Bebre I., Lazdiņa D., Brūmelis G. 2017. Herbaceous plant diversity in energy tree crop plantations. *Acta Biol. Univ. Daugavp.*, 17 (2): 199 – 210.
- Wang W.J., Qiu L., Zu Y.G., Su D.X., An J., Wang H.Y., Zheng G.Y., Sun W. & Chen X.Q. 2011. Changes in soil organic carbon, nitrogen, pH and bulk density with the development of larch (*Larix gmelinii*) plantations in China. *Global Change Biology*, 17(8), 2657–2676.
- Nikodemus O., Melecis V., Kārklīš A., et al. 2008. Augsnis ilgtspējīga izmantošana un aizsardzība. LU Akadēmiskais apgāds, Rīga, 256 p.
- Lutter R., Tullus A., Kanal A., et al. 2016a. The impact of short-rotation hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantations on nutritional status of former arable soils. *Forest Ecology and Management*, 362, 184–193.
- Udawatta R.P. & Jose S. 2011. Carbon sequestration potential of agroforestry practices in temperate North America. In: *Carbon sequestration potential of agroforestry systems*, Kumar B.M. & Nair P.K.R. (Eds), Springer Netherlands, 17–42.
- Bardule A., Rancane S., Gutmane I. et al. 2013. The effect of fertiliser type on hybrid aspen increment and seed yield of perennial grass cultivated in the agroforestry system. *Agronomy Research*, 11(1), 13–24.
- Meiresonne L., Schrijver A.D. & De Vos B. 2006. Nutrient cycling in a poplar plantation (*Populus trichocarpa* × *Populus deltoides*, Beaupre) on former arable land in northern Belgium. *Canadian Journal of Forest Research*, 37, 141–155.
- Lutter R., Tullus A., Kanal A., et al. 2016b. The impact of former land-use type to above- and below-ground C and N pools in short-rotation hybrid aspen (*Populus tremula* L. × *P. tremuloides* Michx.) plantations in hemiboreal conditions. *Forest Ecology and Management*, 378, 79–90.
- Frausto da Silva J.J.R. & Williams R.J.P. 2001. The biological chemistry of the elements. *The inorganic chemistry of life*. Clarendon Press, Oxford, 561 p.
- Smidt S., Jandl R., Bauer H., et al. 2012. Trace metals and radionuclides in Austrian forest ecosystems. In: *The Biosphere*. Ishwaran N. (Ed). InTech, 302 p.
- Lee K.H., Isenhardt T.M. & Schultz R.C. 2003. Sediment and nutrient removal in an established multi-species riparian buffer. *Journal of Soil and Water Conservation*, 58(1), 1–8.
- Allen S., Jose S., Nair P.K.R., et al. 2004. Safety net role of tree roots: experimental evidence from an alley cropping system. *Forest Ecology and Management*, 192, 395–407.
- Nair V.D. & Graetz D.A. 2004. Agroforestry as an approach to minimizing nutrient loss from heavily fertilized soils: the Florida experience. *Agroforestry Systems*, 61, 269–279.
- Jose S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview. *Agroforestry Systems*, 76(1), 1–10.
- Tērauda E. 2008. Ķīmisko vielu plūsmas Latvijas priežu mežu ekosistēmās. Promocijas darbs. Latvijas Universitāte, Rīga, 124 p.
- Tully K.L., Lawrence D. & Scanlon T.M. 2012. More trees less loss: Nitrogen leaching losses decrease with increasing biomass in coffee agroforests. *Agriculture, Ecosystems & Environment*, 161, 137–144.

6. Acknowledgements

The participation in the conference is supported by ERDF project No. 1.1.1.5/18/I/010 "Support to the LSFRI SILAVA for international collaboration projects in research and innovation".

THE EFFECT OF MINERAL AND LIQUID ORGANIC FERTILISERS ON SOIL MINERAL NITROGEN AND CHLOROPHYLL CONTENT IN WINTER WHEAT LEAVES

PhD Stud. Danute Kvasoviene - Petraityte ¹, Dr. Jurgita Ceseviciene ¹, Dr. Ausra Arlauskienė ², Dr. (HP) Alvyra Slepetiene ¹

¹Chemical Research Laboratory, Institute of Agriculture, Lithuanian Research Centre for Agriculture and Forestry, Lithuania

²Joniskelis Experimental Station, Lithuanian Research Centre for Agriculture and Forestry, Lithuania

E-mail: danute.kvasoviene@lammc.lt, jurgita.ceseviciene@lammc.lt

Abstract: The aim of the present study was to compare the effects of mineral and liquid organic fertilisers on the accumulation of nitrate and ammonium nitrogen in a clay loam Endocalcari Endohypogleyic Cambisol and on chlorophyll content in common winter wheat (*Triticum aestivum* L. emend. Fiori et Paol.) leaves. Ammonium nitrate was used as a mineral fertiliser. Liquid bio-fertilisers – pig slurry and anaerobic digestate – were studied with and without nitrification inhibitor (DMPP). In spring, after resumption of winter wheat vegetation, the investigated fertilizers were applied at N_{120} rate. Soil samples were taken from the 0-30 and 30-60 cm soil depths one and a half months after fertilisation. Dry weather prevailed during the study period. Results showed that the mineral nitrogen content in the soil varied depending on the fertiliser used and a slight effect of DMPP was observed. Compared to the unfertilised treatment, the highest and significant increase in mineral (nitrate and ammonium) nitrogen content was determined in the deeper soil layer of the mineral fertilisation treatment. Neither nitrogen rate nor fertilisers of different composition had influence on leaf chlorophyll content.

Keywords: AMMONIUM NITRATE, PIG SLURRY, LIQUID ANAEROBIC DIGESTATE, DMPP, SOIL NITRATE AND AMMONIUM NITROGEN, CHLOROPHYLL CONTENT.

1. Introduction

The interaction among balanced economic development, sustainable farming and natural environment has been receiving increasing attention recently. The efficiency of synthetic N fertilizers is declining as only 47 % of mineral fertilizer nitrogen is converted into products compared with 68 % in 1960 (Ladha et al., 2016). In addition, significant amounts of nitrogen are lost to the environment, wasting resources, endangering air, water, soil and biodiversity, and generating greenhouse gas emissions (Godinot et al., 2014; Lassaletta et al., 2014). Farming systems should be less reliant on resource imports and negative environmental effects should be minimized (Thorup-Kristensen, 2012), with the ultimate goal being production quality not quantity and soil productivity (Sutton et al., 2013).

When using nitrogen from various organic sources (plant residues, green manure, farmyard manure, slurry, waste products of bioenergy production (digestates), composts, etc.), the uptake of nitrogen compounds and its intensity have a marked effect on plant nutrition and productivity (Opheusden et al., 2012) and on soil quality (Bhowmik et al., 2016). According to Johansen et al. (2013), plant and animal-derived digestates stimulate mineralization processes in the soil and increase mineral N content by 30-40 % compared with cattle slurry.

The use of N fertilizers, especially organic liquid, can lead to a loss of nitrogen (N) during and after fertilization, which can have negative environmental effects. Depending on the environmental and soil conditions, ammonium ($N-NH_4$) nitrogen is converted into nitrates ($N-NO_3$). Microbial nitrification and denitrification processes can result in losses of nitrogen oxide (N_2O) causing greenhouse gas emissions. Moreover, $N-NO_3$ is more mobile in the soil than $N-NH_4$, and can therefore leach into deeper soil layers. N-stabilizing nitrification inhibitors capable of slowing $N-NH_4$ conversion to $N-NO_3$ and reducing NO_2 emission are used to reduce potential N losses and increase the value of organic fertilizers (Huérffano – Salinas et al., 2016; Kong et al., 2016; Torralbo et al., 2017; Corrochano-Monsalve et al., 2018). Livestock slurry and biogas digestate have recently been used in large quantities throughout Europe as valuable fertilizers (Insam et al., 2015). It is maintained that digestate can be an effective way to reduce nitrogen losses compared with mineral fertilizers when using the same N rates (Verdi et al., 2019); however, the yield may not always differ significantly (Šimon et al., 2015; Verdi et al., 2019), and the positive effect of total N incorporated with organic fertilizers may be felt after several years (Cavali et al., 2016).

The aim of present study is to determine the accumulation of mineral (nitrate and ammonium) nitrogen in a clay loam soil and chlorophyll content in common winter wheat (*Triticum aestivum* L. emend. Fiori et Paol.) leaves by comparing the effect of mineral fertiliser and liquid organic fertilisers, pig slurry and anaerobic digestate, using them with and without a nitrification inhibitor.

2. Materials and methods

2.1. Site and soil description

The field experiment was conducted in 2018/2019 in the northern part of Central Lithuania's lowland (56°12' N, 24°20' E) at the Joniskelis Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry (LAMMC). Research was carried out on a drained clay loam with deeper lying sandy light loam whose parental rock is limnoglacial clay on morenic loam. According to the classification of Lithuania's soils, it is assigned as Endocalcari Endohypogleyic Cambisol (Cmg-n-w-can). The topsoil (0-30 cm) pH is close to neutral (6.8), moderate in humus (28.1 g kg⁻¹) and total nitrogen (N_{tot} 1.83 g kg⁻¹); medium in available phosphorus (P₂O₅ 141 mg kg⁻¹) and high in available potassium (K₂O 387 mg kg⁻¹).

2.2. Experimental design and details

In the autumn, pre-sowing, complex mineral fertilizers $N_{32}P_{32}K_{32}$ were applied in the experimental field. Fertilizer rates were chosen according to the status of soil available phosphorus and potassium. A winter wheat cultivar 'Patras' was sown at a rate of 4.5 million seeds ha⁻¹. A preceding crop was cereal.

The treatments were laid out in a randomized design with three replications, where every replication is in a separate band. The size of each replicate plot area was 75 m² (15×5 m).

Winter wheat was fertilised after resumption of spring vegetation on March 25, 2019; at BBCH 23-25 growth stage. Fertiliser rate per ha was calculated according to total nitrogen. The experiment included six fertilisation treatments:

1. Control;
2. N_{120} mineral fertiliser – ammonium nitrate (AN);
3. N_{120} pig slurry (PS);
4. N_{120} pig slurry (PS) + DMPP;
5. N_{120} liquid anaerobic digestate (LD);
6. N_{120} liquid anaerobic digestate (LD) + DMPP.

Ammonium nitrate was used for mineral fertilisation, nitrogen (N 344 g kg⁻¹) composition in the fertilizer is 50 % $N-NH_4$ and 50 % $N-NO_3$. Liquid bio-fertilisers were pig slurry and anaerobic digestate, obtained under the controlled biological decomposition of pig slurry and residues of agriculture crops. Both liquid

fertilizers are based on ammonium. A detailed nutrient composition of the applied bio-fertilisers is provided in Table 1.

Table 1. Characteristics of liquid bio-fertilisers

Ferti-liser	pH	DM	Corg	Ntot		N-	N-	P	K
		g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g L ⁻¹	NH ₄ g L ⁻¹	NO ₃ g L ⁻¹	g kg ⁻¹	g kg ⁻¹
PS	7.5	14.3	4.53	2.32	2.37	1.90	0.01	0.23	1.44
LD	8.2	8.0	1.82	1.81	2.13	1.58	0.01	0.07	1.14

3,4-dimethylpyrazole phosphate (DMPP) base product Vizura ® (BASF, Germany) was used as a nitrification inhibitor. It was mixed with liquid bio-fertilisers at a rate of 2 L ha⁻¹.

2.3. Methods of analysis and sampling

Primary soil analyses. The pH was determined by the potentiometric method (C5020, Consort, Belgium) in 1M KCl (1:2.5, w/v). The content of humus was calculated using organic carbon conversion factor 1.72, while after wet combustion organic carbon was determined by a spectrophotometric measurement at 590 nm (UV/Vis Cary 50, Varian Inc., USA) with glucose as a standard (Nikitin, 1999). The content of Ntot was determined after the wet digestion process with sulfuric acid (H₂SO₄) by the Kjeldahl method using a spectrophotometric measuring procedure at 655 nm wavelength. Available potassium (K₂O) and phosphorus (P₂O₅) extractions were done according to the Egner-Riehm-Domingo (A-L) method; measurements were carried out using the flame atomic absorption spectrometry (AAnalyst 200, Perkin Elmer, USA) in accordance with the manufacturer's instructions and spectrophotometry by colour development with molybdate-vanadate at 430 nm, respectively.

Composition of organic fertilisers. The pH of organic fertilisers was measured by the potentiometric method immediately after the homogenization of the fresh sample. Organic carbon (Corg) content was determined in the same way as in soil samples (see above). Ammonium and nitrate nitrogen was analysed spectrophotometrically using LCK 302 and LCK 339 cuvette tests (DR3900, HACH Lange, Germany) by the standard procedure. Before determination of total nitrogen, phosphorus and potassium, the samples were wet digested: for nitrogen and phosphorus with sulphuric acid (H₂SO₄), for potassium with nitric acid (HNO₃) plus hydrogen peroxide (H₂O₂). The content of Ntot was determined by the Kjeldahl method. Total phosphorus concentrations were quantified spectrophotometrically by a colour reaction with ammonium molybdate vanadate reagent at wavelength 430 nm. The total potassium content was determined by the flame atomic absorption.

Fertilisation trial. Soil sampling and analysing. Soil samples were taken from the 0-30 and 30-60 cm soil layers ~ one and a half months after fertilisation (May 13, 2019; BBCH 34-35). Five cores were randomly collected from each plot, crushed and stored in a deep freezer (-18°C) until analysis. The concentrations of nitrate (N-NO₃) nitrogen were determined by the potentiometric method in a 1 % extract of KAl(SO₄)₂·12H₂O (1:2.5, w:v), and ammonium (N-NH₄) nitrogen using a spectrophotometric measurement procedure at a wavelength of 655 nm in a 1M KCl extract (1:2.5, w:v). Soil mineral N content was calculated as the sum of N-NH₄ and N-NO₃.

All chemical analyses of soil and liquid bio-fertilisers were conducted at the Chemical Research Laboratory of the Institute of Agriculture, LAMMC. All concentrations of elements and compounds are expressed on a DM basis.

The relative chlorophyll content in wheat leaves was determined using the SPAD 502 (Konica Minolta, Japan) device, Fig. 1. Wheat plants (15 plant leaves per plot) in the field were monitored twice – at the beginning of stem elongation (BBCH 28-30; April 18, 2019) and in the middle of heading stage (BBCH 54-55; Jun 2, 2019).

2.4. Meteorological conditions

The data show that as little as 10 mm of rainfall fell during the period from winter wheat spring fertilisation to soil sampling

(7 weeks). The long-term average monthly precipitation of April is 37.4 mm, but in 2019 there was no rain in April so at the end of the month the soil was extremely dry. There was more abundant rainfall only at the end of May. April was not only dry, but also warm with the mean air temperature exceeding the long-term average by 2.0°C, the temperature of May was close to the long-term average. Nevertheless this month stood out by several days of heat wave with the temperatures typical of summer.



Fig. 1. Determination of chlorophyll content in leaves with SPAD 502.

2.5. Data analysis

The research data are reported as average values of replications and standard errors. The data were statistically processed using the analysis of variance method (ANOVA) with the SELEKCIJA software package (Raudonius, 2017). Statistical significance of treatments was determined according to F-test probability (P) level and least significant difference (LSD₀₅) values.

3. Results and discussion

3.1. Distribution of mineral nitrogen and its components in the soil

The amount of mineral nitrogen (N-NH₄ and N-NO₃) present in the soil is very important for plant nutrition. Changes in nitrogen content in the soil occur not only through its use by plants, but also due to soil microorganism activity, ambient temperature, soil moisture, organic matter content, fertilisation technologies and other factors (Haynes, 2012). It is therefore very important to know how the amount of mineral N components in the soil changes due to application of different nitrogen fertilisers under respective conditions.

In our research, the effect of fertilisation treatments (Factor B) on soil mineral N components was significant (Table 2). In addition, the amount of nitrogen accumulated at different soil depths (Factor A) differed substantially: significantly higher N-NH₄ and mineral N contents were found in the deeper layer. So, the variation of mineral N in the soil was mainly due to ammonium dynamics.

Such increases in mineral and ammonium nitrogen in the deeper soil layers are essentially characteristic of fertilised soils (Fig. 2). Evident differences were observed in all fertiliser treatments. And this shows that nitrogen applied with fertilisers can migrate from upper soil layers to lower ones not only in the presence of excess moisture (as N-NO₃), but also during periods of moisture shortage (as N-NH₄).

Table 2. Probability (*P*) level of factors and distribution of soil mineral N content and its components in the soil layers

	N-NH ₄	N-NO ₃	Mineral N
Soil layer (Factor A)	<0.000**	0.316ns	0.001**
Fertilisation (Factor B)	0.003**	<0.000**	<0.000**
Interaction	0.077ns	0.004**	0.027*
Factor A	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
0-30 cm	2.61	8.29	10.9
30-60 cm	6.34	9.03	15.4

Note: N-NO₃ – soil nitrate nitrogen, N-NH₄ – soil ammonium nitrogen; ** – $P \leq 0.01$, * – $P \leq 0.05$, ns – $P > 0.05$.

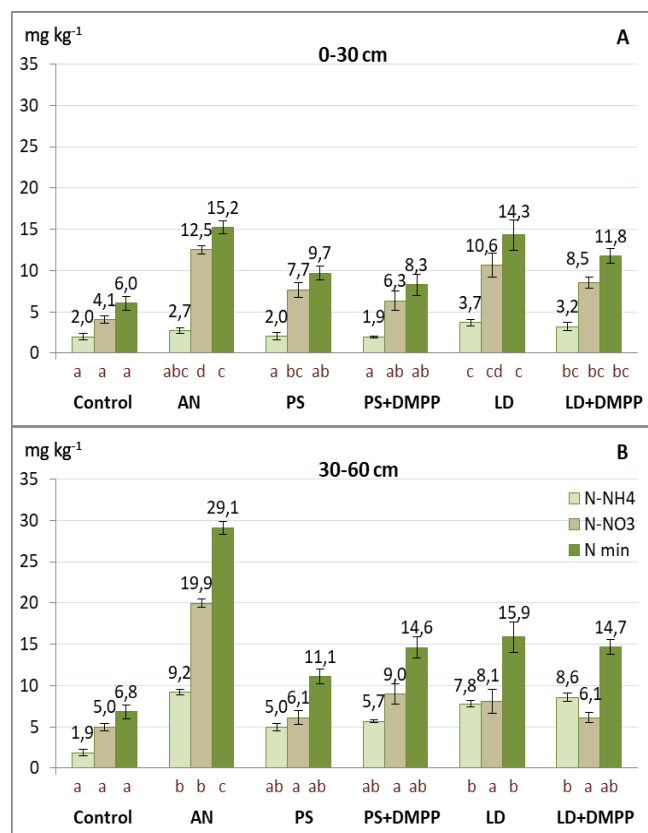


Fig. 2. The influence of fertilisers on mineral nitrogen (Nmin) and distribution of its components (N-NH₄ and N-NO₃) in different soil layers: A. 0-30 cm, B. 30-60 cm. Note: Different letters indicate significant differences among the fertiliser treatments (one way ANOVA, LSD₀₅). Values are means of 3 field replications with error bars as standard errors of the mean.

Comparison of different fertilisers for their nitrogen distribution in the soil showed the highest and significant increase of N-NO₃ and N-NH₄ contents (4.0 and 4.8 times, respectively) in a deeper soil layer when using mineral fertilisation, compared to unfertilised treatment. Fertilisation with N-NH₄-based liquid bio-organic fertilisers also increased the content of mineral N components, but the increase was not as pronounced as in the case of ammonium nitrate fertilisation and not always significant compared with the control. The difference of soil mineral N content in deeper (30-60 cm) soil layer, was insignificant between the liquid fertilizers used but when comparing the influence of these fertilisers in the top soil (0-30 cm), significantly higher mineral N ($P < 0.05$) contents were detected in the anaerobic digestate treatments.

In both organic fertilisers with the nitrification inhibitor DMPP, it tended to reduce the content of N-NO₃ in the top soil compared to equally fertilised treatments without the inhibitor. This finding agrees with that obtained by French researchers in a study dealing with soil tillage and wheat fertilization in which nitrification inhibitors substantially reduced nitrogen losses to the levels in the control in both once and twice fertilized wheat (Corrochano-Monsalve et al., 2018). Kong et al. (2016) have reported that the

nitrification inhibitor DMPP was effective in reducing ammonia oxidation activity.

3.2. Chlorophyll content in winter wheat leaves

The results of winter wheat leaf chlorophyll content measured with SPAD are presented in Fig 3. The chlorophyll content ranged from 51.2 to 55.8 units, and significantly higher values (by on average 4.0), likely due to the drought, were found in leaves at the beginning of stem elongation stage (BBCH 30) than in the middle of heading stage (BBCH 55). Fertilisation did not have significant influence on chlorophyll content (P level – 0.28 and 0.61 at BBCH 30 and BBCH 55 respectively). This partly confirms the results of other researchers who found that nitrogen fertilisers of different composition did not always have a positive effect on the chlorophyll index (Smalstienė et al, 2017).

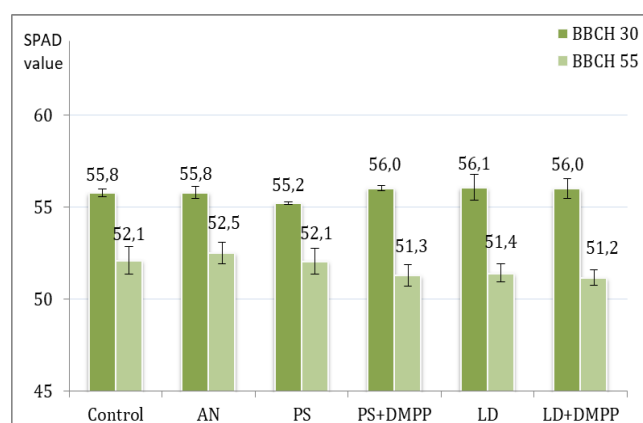


Fig 3. The influence of fertilisers on winter wheat leaf chlorophyll content at different plant growth stages. Note: Values are means of 15 measurement readings with error bars as standard errors of the mean.

4. Conclusions

Results showed that soil mineral nitrogen content varied depending on the fertiliser. The higher content of mineral and ammonium nitrogen in the deeper soil layer is characteristic of N₁₂₀ fertilised soils.

The highest and significant increases in mineral (ammonium and nitrate) nitrogen contents were determined in the deeper (30-60 cm) soil layer when using mineral fertilisation. The differences between organic liquid fertilisers, pig slurry and anaerobic digestate, were not significant, the treatments fertilised with anaerobic digestate tended to have a slightly higher top soil mineral N accumulation.

The denitrification inhibitor DMPP tended to reduce the content of nitrate nitrogen in the top soils, compare to equally fertilised treatments without the inhibitor.

The wheat leaf chlorophyll contents measured with SPAD during the dry weather period were higher at the beginning of stem elongation stage than in the middle of heading stage. Neither nitrogen rate nor fertilisers of different composition had influence on leaf chlorophyll content.

Acknowledgments. This work was part of the long-term research programme “Biopotential and quality of plants for multifunctional use” implemented by the Lithuanian Research Centre for Agriculture and Forestry. The last author acknowledges the project “Quality diagnostics of biogas production by-product (digestate) for innovative use as a biofertilizer” No. DOTSUT-217 (01.2.2-LMT-K-718-01-0053) funded by the Research Council of Lithuania.

5. References

Bhowmik A., A.M. Fortuna, L. Cihacek, A. Bary, C.G. Cogger Use of biological indicators of soil health to estimate reactive

- nitrogen dynamics in long-term organic vegetable and pasture systems – *Soil Biology and Biochemistry*, 103, 2016, 308-319.
- Cavalli D., J. Cabassi, L. Borrelli et al. Nitrogen fertiliser value of digested dairy cow slurry, its liquid and solid fractions, and of dairy cow slurry – *Italian Journal of Agronomy*, 2014, 9 (2), 71-78.
- Corrochano-Monsalve M., X.F. Huérfano, T. Uertes-Mendizabal et al. in: 20th N Workshop and Side event, June 25-27 2018, Rennes, France, 253-254.
- Godinot O., M. Carof, F. Vertčs, P. Leterme SyNE: An improved indicator to assess nitrogen efficiency of farming systems – *Agricultural Systems* 127, 2014, 41-52.
- Haynes R. 2012. *Mineral Nitrogen In The Plant-Soil System*. London, Academic Press, 2012.
- Huérffano-Salinas X., T. Fuertes-Mendizábal, K. Fernández-Díez et al. The new nitrification inhibitor 3,4-dimethylpyrazole succinic (DMPSA) as an alternative to DMPP for reducing N₂O emissions from wheat crops under humid Mediterranean conditions – *European Journal of Agronomy*, 80, 2016, 78-87.
- Insam I., M. Gómez-Brandón, J. Aschera Manure-based biogas fermentation residues – Friend or foe of soil fertility? – *Soil Biology and Biochemistry*, 84, 2015, 1-14.
- Johansen A., M.S. Carter, E.S. Jensen et al. Effects of digestate from anaerobically digested cattle slurry and plant materials on soil microbial community and emission of CO₂ and NO₂ – *Applied Soil Ecology*, 63, 2013, 36-44.
- Kong X., Y. Duan, A. Schramm, J. Eriksen, S.O. Petersen 3,4-Dimethylpyrazole phosphate (DMPP) reduces activity of ammonia oxidizers without adverse effects on non-target soil microorganisms and functions – *Applied Soil Ecology*, 105, 2016, 67-75.
- Ladha J.K., A. Tirol-Padre, C.K. Reddy et al. Global nitrogen budgets in cereals: A 50-year assessment for maize, rice and wheat production systems – *Scientific reports*, 2016, 6-19355.
- Lassaletta L., G. Billen, B. Grizzetti, J. Anglade, J. Garnier 50 year trends in nitrogen use efficacy of world cropping systems: the relationship between yield and nitrogen input to cropland – *Environmental Research Letters*, 9 (10), 2014, 1-9.
- Nikitin B.A. Metod opredeleniya gumusa pochvy [Method for determination of soil humus] – *Agrokimiya*, 5, 1999, 91-93.
- van Opheusden, A.H.M., G.J.H.M. van der Burgt, P.I. Rietberg. Decomposition rate of organic fertilizers: effect on yield, nitrogen availability and nitrogen stock in the soil. No. 2012-033 LbP. Louis Bolk Instituut, 2012.
- Raudonius S. Application of statistics in plant and crop research: important issues – *Zemdirbyste-Agriculture*, 104 (4), 2017, 377-382.
- Smalstienė V., I. Pranckietienė, R. Dromantienė, G. Šidlauskas The influence of different nitrogen forms and application time on winter wheat – *Žemės Ūkio Mokslai [Agricultural Sciences]*, 24 (3), 2017, 81-90.
- Šimon T., E. Kunzová, M. Friedlová The effect of digestate, cattle slurry and mineral fertilization on the winter wheat yield and soil quality parameters – *Plant Soil Environment*, 61 (11), 2015, 522-527.
- Sutton M.A., A. Bleeker, C.M. Howard et al. *Our Nutrient World: The challenge to produce more food and energy with less pollution*, Edinburgh, Centre for Ecology and Hydrology, 2013.
- Thorup-Kristensen K., D.B. Dresbøll, H.L. Kristensen Crop yield, root growth and nutrient dynamics in a conventional and three organic cropping systems with different levels of external inputs and N re-cycling through fertility building crops – *European Journal of Agronomy*, 37 (1), 2012, 66-82.
- Torralbo F., S. Menéndez, I. Barrena, J.M. Estavillo, D. Marino, C. González-Murua Dimethyl pyrazol-based nitrification inhibitors effect on nitrifying and denitrifying bacteria to mitigate N₂O emission – *Scientific report*, 7, 2017, 13810
- Verdi L., P.J. Kuikman, S. Orlandini et al. Does the use of digestate to replace mineral fertilizers have less emissions of N₂O and NH₃? – *Agricultural and Forest Meteorology*, 269-270, 2019, 112-118.

EVALUATION OF BACTERIAL ISOLATES FOR STIMULATING THE GROWTH OF YOUNG MELON (*CUCUMIS MELO* L.) PLANTS

Assist. Prof. Vasileva K. PhD.¹, Ivanova Zh. PhD-student.¹, Assoc. Prof. Tringovska I. PhD.¹,
Maritsa Vegetable Crops Research Institute, Plovdiv, Bulgaria¹

jana-ivanova@abv.bg

Abstract: The unsustainable use of agrochemicals to protect the agricultural crops and increase the yield is one of the reasons for contamination of soil, fresh- and groundwater. As an alternative to chemical fertilizers and pesticides, biofertilization with plant growth-promoting rhizobacteria (PGPR) can cause increasing of yield, diseases and pests resistance. The aim of the current study is to evaluate the potential of some bacterial isolates to stimulate plant growth of young melon plants of two commercial Bulgarian melon cultivars. Melon seedlings at cotyledon stage are inoculated with the bacterial isolates. 35 days after inoculation, the main growth parameters of the plants are measured: fresh and dry weight of shoots, number of leaves, length and thickness of the stem and total leaf area. The obtained results reveal that all of the tested bacterial isolates insignificantly increase the sixth plant growth indexes of Pobeditel melon plants but the best results are observed with B 92 treatment. Plants from Hybrid 1 genotype are positively and significantly influenced by all bacterial isolates. The best results are observed with B 86 treatment - up to 2.7-fold increase in total leaves area and up to 2.4-fold increase in stem length. Plants treated with B 86 also have 50-70% higher shoot fresh and dry weight, 24% thicker stems and 30% higher number of leaves compared to non-inoculated controls. Some of the tested bacterial isolates especially B92 and B97 stimulate the absorption and utilization of major nutrients as N and P.

Keywords: RHIZOBACTERIA, MELON SEEDLINGS, GROWTH STIMULATION

1. Introduction

Over the last 20 years, the European Union has directed its agricultural policy towards reducing dependence on pesticide use due to their harmful effects on the environment, food and human health. In recent years, the disease control in agriculture is focused on alternatives to chemical approaches as biological control of pathogens, enhancing the immunity and resistance of plants and the use of resistant varieties.

Because of the potential of plant growth promoting microorganisms (PGPM) as an alternative to synthetic agrochemicals, they are subject of extensive research [2, 3, 6]. It is known that they can improve soil fertility, stimulate growth by various mechanisms, including soil structure improvement [15], improving resistance to abiotic stress [18, 11], fixing atmospheric nitrogen, degradation of organic matter, dissolving the sparingly soluble nutrients, synthesis and release of biologically active substances [1], as well as suppression of pathogenic microorganisms or induction of plant resistance [7, 13].

Among several, the *Bacillus* spp. have been identified as the predominant communities [10], and some have been commercialized due to their survival within a diverse range of environments, more effective metabolite production and the viability of cells in commercially formulated products [8]. Although this potential there is some inconsistency in plant growth promotion by most PGPM strains under different field conditions and the effectiveness of PGPM is frequently reported to vary depending on the location in which they are applied [12, 4]. In addition to the environmental factors a specific variety response to inoculation may occur. The selection of microbial strains possessing the ability to promote plant growth and health under different environments is still a challenge. Therefore, the aim of the current study is to evaluate the potential of some bacterial isolates to stimulate plant growth of young melon plants of two commercial Bulgarian melon cultivars.

2. Materials and Methods

The experiment was conducted during April-May 2018 in a greenhouse at Maritsa Vegetable Crops Research Institute, Plovdiv, Bulgaria with two commercial melon Bulgarian cultivars – Pobeditel and Hybrid 1. They both are hybrid varieties, developed in Experimental Station for Vegetable Crops, Gorna Oryahovitsa, Bulgaria. Hybrid 1 is characterized by a short vegetation period (about 75 days). The fruits have orange color of the skin and flesh,

and poorly netted skin surface. It is susceptible to downy mildew and powdery mildew. Pobeditel has longer vegetation period (85-95 days). Fruits have poorly netted skin surface and orange color of the skin and flesh. It is resistant to fusarium wilt and powdery mildew.

Six rhizobacterial isolates of plant growth-promoting rhizobacteria, all belonging to *Bacillus* spp. are selected from MVCRI microbial collection - No 85, 86, 92, 97, 246 and 251. These isolates have previously been shown to induce disease resistance in melon.

Melon seeds are sown in surface sterilized plastic pots (one seed per pot) filled with 0.5L sterile perlite, moistened with Hoagland's nutrient solution, containing 1 mM Ca(NO₃)₂; 1 mM KNO₃; 0.4 mM KH₂PO₄; 0.4 mM MgSO₄; 17.9 μM FeEDTA; 4.6 μM H₃BO₃; 0.9 μM MnCl₂; 0.08 μM ZnCl₂; 0.03 μM CuCl₂. At cotyledon stage seedlings are inoculated with 50 mL 48h-old bacterial suspension. Non-inoculated plants from both genotypes served as controls. Pots are arranged in a complete randomized design. Plants are irrigated with sterile Hoagland's nutrient solution once a week at the beginning and twice a week later. Throughout the growing season monitoring and care for the health and physiological status of the plants are undertaken.

At the time of harvest i.e. 35 days after inoculation, the main plant growth parameters are measured – fresh and dry weight of shoots, number of leaves, length, and thickness of the stem, total leaf area [14]. Substrate and plant samples from each treatment are also analyzed at the time of harvest. Water soluble nutrients, pH and electrical conductivity (EC) are determined in aqueous extract 1:1.5 (v/v) according to Sonneveld et al. [16]. The following are quantified: NO₃⁻ – by ion-selective analysis; P – by colorimetric Mo blue reaction; K – by flame photometry; Ca and Mg – by complexometry with EDTA. N, P, K, Ca and Mg are quantified in dried shoots by N – Kjeldahl method; P – colorimetry, K – flame photometry, Ca and Mg – complexometry after dry ashing and subsequent extraction with 2 M HCl. Plant nutrient uptake is calculated by multiplying plant dry matter to the concentration of the certain element in plant tissues.

Each treatment is repeated in triplicate; each replication is composed by 3 plants. Data are subjected to Duncan's Multiple Range Test to separate means. Two-way ANOVA with melon genotype and bacterial isolate as fixed factors is also applied.

3. Results and Discussion

Analysis of variance conducted individually on each plant growth index show that melon genotype influenced shoot fresh and dry weight, leaves number and stem diameter and contribute to 22-26% from the total variation, while bacterial isolate influence shoot dry weight, leaves number, stem length and thickness and total leaves area, and contribute to 18-50% from the total variation (Table 1). Melon genotype x Bacterial isolate interaction is also significant only for total leaves area. Considerable contribution to the total variation (24-44%) has so called error, which suggests that factors, other than examined, influence plant growth parameters.

Table 1: Analysis of variance for the effect of melon genotype and bacterial isolate on some plant growth indexes

Source of variation	df	Sum of squares					
		Shoot fresh weight, g	Shoot dry weight, g	Leaves number	Stem height, cm	Stem thickness, mm	Total leaf area, cm ²
Genotype (A)	1	102,5 ***	4,0 ***	10,5 ***	29,7	2,5 ***	1858,7
Bacterial isolate (B)	6	83,5	5,1 **	10,5 **	2150,7	2,4 **	47754,4 ***
AxB	6	88,1	1,9	3,8	1296,1	1,2	22483,0 **
Error	28	174,6	6,9	11,3	2713,2	3,3	23238,0
Corrected total	41	448,6	17,9	36,1	6189,6	9,4	95334,0

*, **, *** - significance at 5%, 1% and 0.1% probability level respectively

Plant response of the two melon genotypes to inoculation with different bacterial isolates are presented in Table 2. All of the tested bacterial isolates insignificantly increase the sixth plant growth indexes of Pobeditel melon plants but the best results are observed with B92 treatment. Plants from Hybrid 1 genotype are also positively influenced by all bacterial isolates and the differences between treatments and non-inoculated control are significant in most of the cases. The best results are observed with B86 treatment which increase significantly all tested plant growth indexes. Up to 2.7-fold increase in total leaves area and up to 2.4-fold increase in stem length are observed due to bacterial inoculation. Plants treated with B86 also have 50-70% higher shoot fresh and dry weight, 24% thicker stems and 30% higher number of leaves compared to non-inoculated controls.

Table 2: Plant growth indexes of plants from melon two genotypes inoculated with bacterial isolates, 35 days after inoculation

Melon genotype	Bacterial isolate	Shoot fresh weight (g)	Shoot dry weight (g)	Stem length (cm)	Stem thickness (mm)	Number of leaves	Total leaf area (cm ²)
Pobeditel	C	10,5 ^c	3,33 ^{ab}	30,7 ^{b-d}	3,8 ^{de}	5,2 ^d	159,4 ^d
	B 85	12,5 ^{b-e}	3,77 ^{ab}	37,6 ^{b-d}	4,1 ^{b-e}	5,5 ^{b-d}	187,0 ^{b-d}
	B 246	10,8 ^{de}	3,13 ^b	34,6 ^{b-d}	4,0 ^{c-e}	5,8 ^{b-d}	180,6 ^{cd}
	B 86	11,9 ^{c-e}	3,43 ^{ab}	45,3 ^{a-c}	4,3 ^{a-d}	5,5 ^{b-d}	201,2 ^{b-d}
	B 92	14,0 ^{b-e}	4,13 ^a	50,0 ^{ab}	4,2 ^{b-d}	6,0 ^{b-d}	239,6 ^{ab}
	B 97	12,0 ^{c-e}	3,77 ^{ab}	41,6 ^{b-d}	4,1 ^{b-e}	5,3 ^{cd}	210,8 ^{a-d}
	B 251	11,6 ^{c-e}	3,37 ^{ab}	35,7 ^{b-d}	3,5 ^c	5,8 ^{b-d}	198,0 ^{b-d}
Hybrid 1	C	11,7 ^{c-e}	1,87 ^c	25,5 ^d	3,9 ^{c-e}	5,2 ^d	94,9 ^e
	B 85	11,9 ^{c-e}	3,20 ^{ab}	28,3 ^{cd}	4,1 ^{b-e}	6,2 ^{b-d}	187,6 ^{b-d}
	B 246	15,4 ^{a-d}	3,23 ^{ab}	43,9 ^{a-d}	4,9 ^a	7,7 ^a	262,4 ^a
	B 86	19,7 ^a	2,80 ^b	60,6 ^a	4,9 ^a	6,7 ^{ab}	260,7 ^a
	B 92	13,6 ^{b-e}	3,50 ^{ab}	32,3 ^{b-d}	4,5 ^{a-c}	6,5 ^{a-c}	213,4 ^{a-d}
	B 97	17,0 ^{ab}	3,03 ^b	31,5 ^{b-d}	4,7 ^{ab}	6,5 ^{a-c}	220,4 ^{a-c}
	B 251	15,8 ^{a-c}	2,97 ^b	41,7 ^{b-d}	4,5 ^{a-c}	7,5 ^a	230,5 ^{a-c}

C – Control, non-inoculated

a, b, c – Values in columns followed by different letters are significantly different at P<0.05, Duncan's Multiple Range Test

Growth promotion induced by rhizospheric bacteria is observed also by other authors [5, 19]. The proposed mechanisms of action include improved nutrition and production of biologically active

substances [17]. As reviewed by Hashem [9] the observed growth promotion of plants after inoculation with *Bacillus* spp. is attributed mainly to the synthesis of phytohormones, which stimulate root development and thus influence nutrient uptake.

The analyses of the potting mixtures are presented in Table 3. Inoculated and non-inoculated substrates have similar EC values as well as similar concentrations of available nutrients. This is due to the use of inert substrate which is extremely poor in nutrients and the use of the same nutrient solution in all treatments to maintain nutrients levels.

Table 3: Characterization of the potting media 35 days after inoculation of two melon genotypes with rhizobacteria

Melon genotype	Bacterial isolate	pH	EC (mS.cm ⁻¹)	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Pobeditel	C	7,29 ^{cd}	0,20 ^{a-d}	1,7 ^b	3,5 ^c	3,7 ^a	18,0 ^a	9,6 ^{b-d}
	B 85	7,22 ^d	0,23 ^{a-d}	1,7 ^b	6,1 ^{a-c}	8,7 ^a	19,0 ^a	9,6 ^{b-d}
	B 246	7,32 ^{b-d}	0,27 ^a	4,0 ^b	7,2 ^{ab}	9,5 ^a	17,0 ^{ab}	12,5 ^{ab}
	B 86	7,27 ^{cd}	0,19 ^{b-d}	3,0 ^b	4,7 ^{bc}	3,7 ^a	16,0 ^{ab}	10,2 ^{b-d}
	B 92	7,27 ^{cd}	0,22 ^{a-d}	0,7 ^b	5,9 ^{a-c}	8,3 ^a	16,0 ^{ab}	10,8 ^{a-c}
	B 97	7,58 ^a	0,23 ^{a-d}	3,0 ^b	6,3 ^{ab}	8,3 ^a	13,0 ^{ab}	10,8 ^{a-c}
	B 251	7,43 ^{a-c}	0,22 ^{a-d}	3,7 ^b	6,7 ^{ab}	6,2 ^a	13,0 ^{ab}	13,8 ^a
Hybrid 1	C	7,34 ^{b-d}	0,21 ^{a-d}	8,0 ^b	7,0 ^{ab}	6,2 ^a	15,0 ^{ab}	10,2 ^{b-d}
	B 85	7,57 ^a	0,25 ^{a-c}	10,0 ^b	7,4 ^{ab}	8,3 ^a	17,0 ^{ab}	11,3 ^{ab}
	B 246	7,58 ^a	0,26 ^{ab}	8,0 ^b	8,4 ^a	8,3 ^a	19,0 ^a	10,2 ^{b-d}
	B 86	7,50 ^{ab}	0,21 ^{a-d}	4,0 ^b	5,7 ^{bc}	6,2 ^a	15,0 ^{ab}	9,6 ^{b-d}
	B 92	7,24 ^{cd}	0,17 ^d	6,7 ^b	5,0 ^{bc}	6,2 ^a	11,0 ^b	10,8 ^{a-c}
	B 97	7,26 ^{cd}	0,16 ^d	9,7 ^b	5,8 ^{a-c}	6,2 ^a	12,0 ^{ab}	7,8 ^{cd}
	B 251	7,18 ^d	0,18 ^d	26,7 ^a	6,6 ^{ab}	5,4 ^a	19,0 ^a	7,2 ^d

C – Control, non-inoculated

a, b, c – Values in columns followed by different letters are significantly different at P<0.05, Duncan's Multiple Range Test

The concentration of the five nutrients in shoots as percentage from the dry weight is similar between treated and non-treated plants, irrespectively from the cultivar (Table 4). Nevertheless, some significant differences with the controls are observed: higher concentration of N in B97 treatment in Hybrid 1 shoots; higher concentration of P in B251 treatment in Pobeditel shoots; lower concentration of P in B92 treatment in Hybrid 1 shoots; lower concentration of Ca in B85, B86, B92 and B97 treatments in Hybrid 1 shoots.

Table 4: Nutrient concentration in melon shoots, 35 days after inoculation with rhizobacteria

Melon genotype	Bacterial isolate	N (mg.g ⁻¹)	P ₂ O ₅ (mg.g ⁻¹)	K ₂ O (mg.g ⁻¹)	CaO (mg.g ⁻¹)	MgO (mg.g ⁻¹)
Pobeditel	C	19,2 ^{cd}	7,9 ^{de}	12,2 ^{ns}	13,1 ^c	11,4 ^{a-c}
	B 85	21,5 ^{b-d}	9,0 ^{a-e}	9,0 ^{ns}	14,9 ^{a-c}	7,9 ^{bc}
	B 246	21,4 ^{b-d}	9,3 ^{a-d}	6,0 ^{ns}	10,5 ^c	12,7 ^{ab}
	B 86	18,5 ^d	7,7 ^e	7,0 ^{ns}	11,2 ^c	15,3 ^a
	B 92	19,6 ^{b-d}	8,4 ^{b-e}	11,0 ^{ns}	11,9 ^c	11,1 ^{a-c}
	B 97	22,0 ^{b-d}	9,2 ^{a-d}	7,0 ^{ns}	12,7 ^c	10,8 ^{a-c}
	B 251	21,4 ^{b-d}	10,1 ^a	7,0 ^{ns}	14,5 ^{a-c}	7,7 ^c
Hybrid 1	C	22,0 ^{b-d}	9,3 ^{a-d}	13,1 ^{ns}	19,8 ^a	10,9 ^{a-c}
	B 85	24,7 ^{ab}	9,7 ^{a-c}	13,0 ^{ns}	14,1 ^{bc}	6,9 ^c
	B 246	23,7 ^{a-c}	9,2 ^{a-e}	10,6 ^{ns}	15,6 ^{a-c}	9,0 ^{bc}
	B 86	21,2 ^{b-d}	8,2 ^{c-e}	11,9 ^{ns}	13,2 ^c	11,8 ^{a-c}
	B 92	20,4 ^{b-d}	7,7 ^e	6,0 ^{ns}	10,4 ^c	11,6 ^{a-c}
	B 97	27,1 ^a	10,3 ^a	12,9 ^{ns}	12,6 ^c	9,5 ^{bc}
	B 251	21,9 ^{b-d}	9,8 ^{ab}	11,5 ^{ns}	19,3 ^{ab}	12,7 ^{ab}

C – Control, non-inoculated

a, b, c – Values in columns followed by different letters are significantly different at P<0.05, Duncan's Multiple Range Test

Beside concentration of certain nutrients in shoot tissues their content in shoots is also quantified (Table 5). In both cultivars the increased content of both N and P is observed due to treatment with

B92 and B97. Inoculation with B251 has led to increased content of P, while B86 – to increased content of Mg.

Table 5: Nutrient content in melon shoots, 35 days after inoculation with rhizobacteria

Melon genotype	Bacterial isolate	N (mg.g ⁻¹)	P ₂ O ₅ (mg.g ⁻¹)	K ₂ O (mg.g ⁻¹)	CaO (mg.g ⁻¹)	MgO (mg.g ⁻¹)
Pobeditel	C	62,9 ^{cd}	26,4 ^{bc}	44,1 ^{ab}	45,8 ^{a-d}	31,2 ^{b-d}
	B 85	80,6 ^{a-c}	33,7 ^{ab}	33,7 ^{a-d}	55,2 ^a	30,3 ^{cd}
	B 246	67,2 ^{a-d}	29,1 ^{ab}	18,8 ^d	32,6 ^d	40,3 ^{a-c}
	B 86	63,9 ^{b-d}	26,4 ^{bc}	23,8 ^{b-d}	38,4 ^{b-d}	52,6 ^a
	B 92	81,0 ^{ab}	34,6 ^a	45,5 ^a	49,2 ^{a-c}	46,0 ^{ab}
	B 97	81,3 ^{ab}	34,3 ^a	26,1 ^{a-d}	48,1 ^{a-c}	38,6 ^{a-c}
Hybrid 1	B 251	72,1 ^{a-d}	34,1 ^a	23,5 ^{b-d}	48,7 ^{a-c}	26,2 ^{cd}
	C	40,2 ^e	16,9 ^d	24,0 ^{b-d}	36,2 ^{b-d}	19,9 ^d
	B 85	78,2 ^{a-c}	30,7 ^{ab}	40,4 ^{a-c}	44,6 ^{a-d}	21,6 ^d
	B 246	76,4 ^{a-c}	29,6 ^{ab}	33,1 ^{a-d}	50,5 ^{ab}	28,9 ^{cd}
	B 86	56,6 ^d	22,0 ^{cd}	29,0 ^{a-d}	32,6 ^d	38,8 ^{a-c}
	B 92	70,7 ^{a-d}	26,7 ^{bc}	20,9 ^{cd}	34,7 ^{cd}	39,4 ^{a-c}
	B 97	82,4 ^a	31,2 ^{ab}	40,5 ^{a-c}	38,7 ^{b-d}	28,9 ^{cd}
	B 251	63,4 ^{b-d}	28,8 ^{a-c}	31,9 ^{a-d}	55,5 ^a	37,1 ^{bc}

C – Control, non-inoculated

a, b, c – Values in columns followed by different letters are significantly different at P<0.05, Duncan's Multiple Range Test

The results obtained here concerning the nutrients concentration and content in plant shoots suggest that some of the tested bacterial isolates especially B92 and B97 stimulate the absorption and utilization of major nutrients as N and P.

4. Conclusions

The obtained results revealed that all of the tested bacterial isolates insignificantly increase the sixth plant growth indexes of Pobeditel melon plants but the best results are observed with B92 treatment. Plants from Hybrid 1 genotype are positively and significantly influenced by all bacterial isolates. The best results are observed with B86 treatment – up to 2.7-fold increase in total leaves area and up to 2.4-fold increase in stem length. Plants treated with B86 also have 50-70% higher shoot fresh and dry weight, 24% thicker stems and 30% higher number of leaves compared to non-inoculated controls. Some of the tested bacterial isolates especially B92 and B97 stimulate the absorption and utilization of major nutrients as N and P.

Acknowledgment

The research leading to these results has received funding from National Science Fund under Bulgarian Ministry of Education and Science (grant No DM16/1 – 11.12.2017).

References

- Altieri M., C. Nicholls. Agroecology Scaling Up for Food Sovereignty and Resiliency. Book: Sustainable Agriculture Reviews. 2012, 11:1-29.
- Artursson V., R. Finlay, J. Jansson. Interactions between arbuscular mycorrhizal fungi and bacteria and their potential for stimulating plant growth. Environ Microbiol. 2006, 8:1-10.
- Berg G. Plant-microbe interactions promoting plant growth and health: perspectives for controlled use of microorganisms in agriculture. Appl Microbiol Biotechnol. 2009, 84:11-18.
- Bly U., H. Woodard, R. Gelderman. Biological inoculants and other products for soybeans during 2009, (44309 and 44409) Soil/Water Research South Dakota State University, Research Progress Report, 2009.

5. Brudman S., E. Jurkevitch, Y. Okon. Recent advances in the use of plant growth promoting rhizobacteria (PGPR) in agriculture. In: Subba RN, Dommergues YR (eds) Microbial interactions in agriculture and forestry, Science Publishers, Plymouth, 2000, 2:29-250.

6. De Souza R., A. Ambrosini, L. Passaglia. Plant Growth-Promoting Bacteria as Inoculants in Agricultural Soils. Genetics and Molecular Biology. 2015, 38(4): 401-419.

7. Duffy B., G. Défago, K. Duffy. Environmental Factors Modulating Antibiotic and Siderophore Biosynthesis by *Pseudomonas Fluorescens* Biocontrol Strains Appl Environ Microbiol. 1999, 65(6): 2429-38.

8. Haas, D., G. Defago. Biological control of soil-borne pathogens by fluorescent pseudomonads, Nat Rev Microbiol. 2005, 3:307-319.

9. Hashem A., B. Tabassum, E. Fathi Abd_Allah. *Bacillus subtilis*: A plant-growth promoting rhizobacterium that also impacts biotic stress *Bacillus subtilis*: A plant-growth promoting rhizobacterium, Saudi Journal of Biological Sciences, 2019.

10. Kang S. M., R. Radhakrishnan, K. E. Lee, Y. H. You, J. H. Ko, J. H. Kim et al. Mechanism of plant growth promotion elicited by *Bacillus sp.* LKE15 in oriental melon. Acta Agric Scand Sect B Soil Plant Sci. 2015, 65:637-647.

11. Mayak S., T. Tirosh, B. R. Glick. Plant growth-promoting bacteria confer resistance in tomato plants to salt stress. Plant Physiol Biochem. 2004, 42:565-573.

12. McSpadden-Gardener B. B. Ecology of *Bacillus* and *Paenibacillus* spp. in agricultural systems. Phytopathology. 2004, 94(11):1252-1258.

13. Nagesh M., P. Parvatha-Reddy. 2004. Biochemical changes in *Glomus fasciculatum* colonized roots of *Lycopersicon esculentum* in presence of *Meloidogyne incognita*. Indian J Exp Biol. 2004, 42:721-727.

14. Panta G. R., D. S. NeSmith. A model for estimating area of muskmelon leaves, Hortscience. 1995, 30(3):624-625.

15. Rillig M., D. Mummey. Mycorrhizas and soil structure. New Phytol. 2006, 171:41-53.

16. Sonneveld C., J. Van Den Ende, P. A. Dijk. Analysis of growing media by means of a 1:1.5 volume extract. Soil Science and Plant Analysis. 1974, 5(3):183-202.

17. Vessey J. Plant Growth Promoting Rhizobacteria as Biofertilizers. Plant and soil. 2003, 255(2): 571-86.

18. Vivas A., A. Marulanda, J. Ruiz-Lozano, J. Barea, R. Azcon. Influence of a *Bacillus sp.* on physiological activities of two arbuscular mycorrhizal fungi and on plant responses to PEG-induced drought stress. Mycorrhiza. 2003, 13:249-256.

19. Xie S. S., H. J. Wu, H. Y. Zang, L.M. Wu, Q. Q. Zhu, X. W. Gao. Plant Growth Promotion by Spermidine-Producing *Bacillus Subtilis* OKB105. Molecular plant-microbe interactions. 2014, 27(7): 655-63.

EVAPOTRANSPIRATION WITH STRAWBERRIES GROWN IN DRIP IRRIGATION CONDITIONS

Assoc. Prof. PhD R. Kireva, Prof. PhD M. Mihov

Institute of Soil Science, Agricultural Technology and Plant Protection "Nikola Pushkarov", Sofia, Bulgaria

Email: R.Kireva@abv.bg; M.Mihov@abv.bg

Summary: *Evapotranspiration of a strawberry, ever-bearing variety Polka in three-year (2011- 2013) field experiments with drip irrigation on leached cinnamon forest soil in the area of Chelopechene, Sofia district. Different irrigation regimes have been tested: from fully satisfying the daily needs of the crop from water to irrigation with 20% and 40% reduced irrigation rates.*

During the research period, the total evapotranspiration rate for the strawberry growing season was 213 mm in average. Average 24-hour values vary by date. The highest are in the first and second ten-day period of June (harvest period).

KEY WORDS: EVAPOTRANSPIRATION, STRAWBERRY, IRRIGATION DEPTH, DRIP IRRIGATION.

Introduction

When maintaining optimal soil moisture and sufficient water for evapotranspiration (ET), it is determined by two factors: the weather conditions and the duration of the vegetation of the crop. The evapotranspiration of each crop (as well as that of strawberries) is a major cost element in the water balance of the active soil layer and is one of the main factors determining the parameters of the irrigation regime. The intensity of ET influences directly the duration of the inter-election period, ie. the number of irrigations and the size of the irrigation rate.

For the conditions of our country the total evapotranspiration of strawberries during the vegetation period is 750 - 810 mm for the regions with lower altitude, while for the foothills it is 10 - 15% smaller, as the requirements of the plants during the vegetation period of water are different. They are most demanding when they are growing and ripening (Ivanov, 1998). The results of our studies under the conditions of our country prove that it is reasonable and correct to calculate the evapotranspiration by a formula based on the sum of the average daily air temperature. (Zahariev 1985, Kalsheva 1991).

Drip irrigation is the technology that is increasingly used for irrigation of berry crops due to the advantages and compared to gravity irrigation and sprinkling: water savings (20-60%); lower labor costs (40-80%); increase of the quantity and improvement of the yield quality (20-60%), possibility of feeding the fertilizers simultaneously with the water; uniform distribution of water over the area, etc.

These drip irrigation capabilities are realized thanks to the specific mode of action of the irrigation system in which the water is fed to certain points around the plants and flows directly into the area where their roots are located by wetting only a limited part of the soil surface and the soil without seepage or filtration, and the watering is carried out on small and frequent irrigations corresponding to the water consumption of the crops, which allows the humidity in the soil root layer to be maintained and during the entire growing season about a higher value without any significant fluctuations and placing the plants in the water stress (Bucks et al., 1982).

This method fully meets the requirements for sustainable agriculture and organic production of fruit, incl. provision of high yields of product quality, reduces undesirable side effects (Branson et al., 1981),

The aim of the paper is to determine the size of the evapotranspiration of strawberries grown in drip irrigation on cinnamon forest soil (leached) in the Sofia field.

Methodology of research

In order to establish the evapotranspiration of Polka variety strawberries in the period 2011-2013, a field experiment was performed on a field of experiments of NPASP N. Pushkarov in Chelopechene, Sofia. The following irrigation variants were tested at a pre-irrigation humidity of 85-90% of WHC (Water holding capacity):

1. Irrigation with Water application rate 100% M;
2. Irrigation with Water application rate 80% M;
3. Irrigation with Water application rate 60% M.

The magnitude of the irrigation rate is calculated using the Kostyakov formula, modified by the coefficients of Fercman, Garzoli (1980), taking into account the planting pattern - base-own root, forming -line: 0,8 x 0,15-0, 25 m, two-line: 0.9-1.0 x 0.35 x 0.20-0.25 m. To monitor the dynamics of soil moisture, soil samples were taken at variance (100% irrigation rate) at a depth of 0-50 cm across 10 cm, which were processed by the weight-thermostatic method. Based on the data on soil moisture dynamics during the vegetation period, the irrigation carried out and the fallen rain using the water balance method, the strawberry evapotranspiration was calculated by ten days period and for the whole vegetation period. The limit values of the individual elements of the irrigation regime were established experimentally.

The soil is cinnamon forest (leached), slightly sandy-clayey in the ore layer formed on the base of old deluvial cone-shaped materials. It is depleted with nitrogen (mineral N 17.3 mg / kg), on average with phosphorus (P_2O_5 14.4 mg / 100g) and well stocked with potassium (K_2O 45.4 mg / 100 mg / kg). On average, for the 0-60 cm layer, the soil has the following water-physical properties: WHC = 22.1%, wilting point - 12.3%, compared to the weight of absolutely dry soil; volume weight at WHC - 1.47 g / cm³. For the soil layer 0-100 cm, the same values have values: WHC - 21.8%, wilting point - 12.3% and bulk density - 1.50 cm³. Experimental establishment of strawberry evapotranspiration for the vegetation period is based on the data on soil moisture dynamics during the vegetation period and on the surface waterings for variant 1 over 10 cm and for the soil layer 0-50 cm depth where the layer is more than 85% of the root system of strawberries, using the water balance method.

The water-based calculations were made using the formula:

$$ET = W_{\text{нач}} - W_{\text{кр}} + m,$$

where: ET – evapotranspiration in mm;

$W_{\text{нач}}$ – water reserve in the layer 0-50 cm at the beginning of the period, in which ET is calculated, mm;

$W_{\text{кр}}$ – water reserve in the layer 0-50 cm at the end of the period, mm;

m – water application rate, mm.

Installation for drip irrigation of outdoor strawberries

The drip irrigation installation consists of a command node and three irrigated batteries. The control unit includes a master tap for water entry and measurement, a filter and an injector for feeding fertilizers into the plant along with irrigation water and the necessary connecting elements.

Each irrigation battery can operate independently. It consists of a distribution pipe of PE pipes with a diameter of ϕ 40 with a length of 12 m and seven irrigation wings with a length of 18 m. Separation of irrigation wings from the distribution pipeline is carried out with a water absection with a fitted plastic shut-off faucet for self-activating and deactivating the operation of the wings. The scheme of the drip irrigation installation and the parameters of its main elements are designed to ensure a uniform distribution of the irrigation rate along the rows of strawberries.

The required watered area around the plants depends on the development of their root system. It is generally assumed that the area where the roots extends is equal to the area covered by the plant crown and should be moistened.

Results and discussions

Meteorological characteristics

In the cultivation of strawberries, one of the most important meteorological factors, which depends to a large extent on the yield quantity, is the amount of precipitated rainfall.

The coverage of rainfall for the April-September period in the fifty-year series characterizes the vegetation period of the crop during the years of research as very dry with a rainfall guarantee of 80% (2013) to 86% (2012) fewer rainfalls have fallen in 2011 (244mm) and 2012. (245mm), and in 2013 (260mm), (Table 1). Fallen rainfall during the vegetation of the crop is unevenly distributed, which has led to the realization of irrigation in the three years of experience. The temperature for the period April-September characterizes 2012 (3510,0 °C) and 2013 (3300,7 °C), with very warm and 2011 (3137,0 °C) as warm with a guarantee of 5,36% to 1, 36%

Table 1 Rainfall during strawberry vegetation period (2011 – 2013 z.)

PERIODS	YEARS		
	2011	2012	2013
April-September	244	245	260
April-september Longtermaverage (50 years)	365	365	365
May-Jun	73	114	188
Mdy-Jun Longtermaverage (50 years)	156	156	156

The need for irrigation to maintain optimal soil moisture in the layer 0-50 cm is mainly due to the quantity and distribution of rainfall during the vegetation of the crop. The irrigations are realized when the soil moisture in the layer 0-50 cm drops below 85% of the WHC. On average during the research period during the vegetation period of strawberry, eight irrigations were applied with an average irrigation rate of 17.2 mm and an irrigation rate of 137.6 mm were submitted, the water application rates being implemented for the period from the beginning of May to the end of June.

The intervals between irrigations for strawberries growing season are of varying length and depend on the quantity and distribution of rainfall, as well as the stages of the development of the crop. It has been found that the requirements of strawberries for soil moisture are greater in the periods of flowering, ripening and harvesting of

fruit, where the highest number of irrigations has been realized, which is why moisture in the soil during this period should be maintained in range 80-85% of WHC. (Table 2),

Table 2 Averagnumber of irrigation during vegetation season of strawberry with application of the 100% required water depth

DEVELOPMENT STAGES	NUMBER IRRIGATIONS	IRRIGATION PERIODS
1.Initial stage	0	1 st Decade of April
2. Beginning of flowering	0-1	3 rd Decade of April
3.Full flowering	2	May
4. Ripening and harvesting of fruits	4-5	June

Establishing the evapotranspiration of each culture is one of the major issues in meliorations and essential for the design and operation of irrigation systems.

It varies depending on the weather conditions. For the years of the experiment, the highest values reached 246 mm in 2012, and in the other two years the values are close, respectively 192 mm for 2011 and 202 mm for 2013. This is due to the similar weather conditions of these years (Table 3). On average, during the research period, the total ET for the strawberry growing season is 213 mm. (Table 3).

In order to satisfy the plants' needs of water, it is necessary to establish the rate of change of the evapotranspiration by ten days and on average over the period. In this aspect, the practical value associated with the forecast has the option of having an optimal irrigation rate.

Year-on-year evapotranspiration ranges from 1.5 to 5.5 mm, with the highest values reaching 2013 in the third ten days of May and the first ten days of June (Figure 1)

For the experimental years the mean daily values of the evapotranspiration range from 1.6 to 4.8 mm. In the initial phase of the development of the crop, the values are lower, due to the smaller size of the plants, which use insignificant quantities of water and the lower evaporation capacity of the atmosphere. Optimization of soil moisture increases the water consumption of strawberry, the degree of growth depends on the climatic situation in the given year and the number of water courses. Data for years of experience is given in Table 3.

With entering of strawberry plants in an intensive growth phase at beginning in May, a more intense increase in ET is observed. In the second and third ten day period of May, it reached 3.5-4.5 mm on average during the study period. The maximum average daily values of evapotranspiration are related to the ripening period, fruit harvesting, which coincides with the period of high evaporation capacity of the atmosphere. This period covers the entire month of June. The maximum ET is in the first ten days of June. In individual years, it varies from 4.5 to 4.8 mm (Table 3), (Figure 1).

The calculated ten-day values of the biophysical coefficient Z based on the experimental determination of the evapotranspiration and the daily sums of the average daily air temperature calculated by the formula (Delibaltov, Hristov et al., 1962) are presented in Table 3 and Fig.1-2.

Changes in the values of this coefficient follow the changes in the evapotranspiration during the growing season of the crop and reflect the specificity of water consumption depending on the biological requirements of the crop, the stage of development, the manifestations of the meteorological factors.

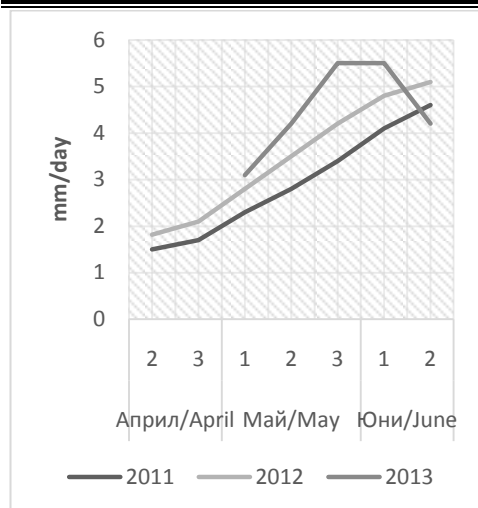


Figure 1. Average daily evapotranspiration by years

The set values of the biophysical coefficient Z represent an objective basis for determining the project irrigation regime and predicting the time for irrigation of the crop.

On average for the experimental period, the values of the biophysical factor Z of the culture range from 0.14 to 0.29, their values being the lowest at the beginning of the growing season and the highest during the formation and ripening of the fruits. These results give a real opportunity to develop the design and

exploitation of the irrigated regime of strawberries in the conditions of water deficit.

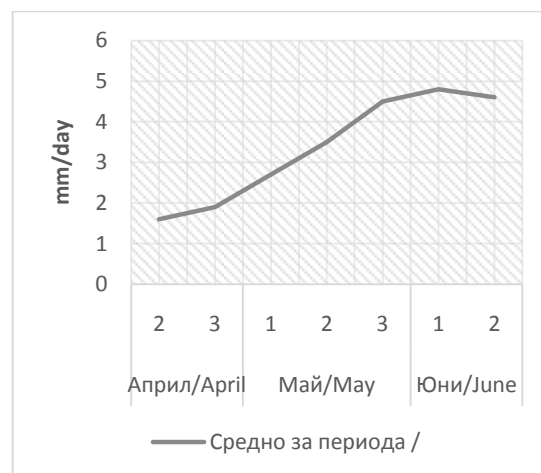


Figure 2. Average daily evapotranspiration, average for 2011-2013

Table 3 Evapotranspiration of strawberry during vegetation period

Months	Evapotranspiration, mm/day					Biophysical coefficient
	10 days	2011	2012	2013	3 years average	Average
		mm/day	mm/day	mm/day	mm/day	in ten days
April	2	1,5	1,82	-	1,6	0,14
	3	1,7	2,1	-	1,9	0,16
May	1	2,3	2,8	3,1	2,7	0,18
	2	2,8	3,5	4,2	3,5	0,23
	3	3,4	4,2	5,5	4,5	0,29
June	1	4,1	4,8	5,5	4,8	0,25
	2	4,6	5,1	4,2	4,6	0,23
Sum for vegetation period		192	246	202,0	213	medium for vegetation 0,21

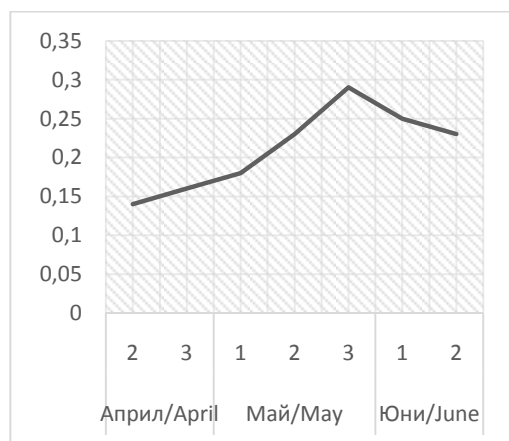


Figure 3 Values of the biophysical coefficient Z average for the period 2011-2013

Conclusions

1. it is established that the total evapotranspiration rate for the growing season for strawberries is 213 mm in average.
2. The average daily values of evapotranspiration have been established. In the individual years of the experiment, they range from 1.5 to 5.5 mm and reach maximum values during the first ten-day period of June (ripening period, fruit harvesting).

3. It is shown that the dynamics of the average daily values of the evapotranspiration during the vegetation period follows the stages in the development of the culture and the changes of the meteorological factors.

4. The determined biophysical coefficient values (Z) provide an objective basis for determining the irrigation regime and forecasting irrigation periods for the crop.

References:

- Delibaltov, Y.,** H.Hristov, Iv.Zonev, 1962. Desing irrifation scheduling for agricultural crops. Ppoc.-IHM,3, p.5-56, (Bg).
- Zahariev, T.,** 1985. On Methods and Formulas for Determining the Evapotranspiration of Agricultural Cultures, in Support of Technical Progress in Water Management, vol. 2, p.3-10, (Bg).
- Ivanov, A.L.,** 1998, Studies on irrigation of strawberry, raspberry and blackcurrant by dropping, Habilitation work, Kostinbrod, p.51, (Bg).
- Kalsheva, Sp.,** 1991, Participates in the groundwater in the eutonpression of agricultural crops., Dissertation, p.134, (Bg).
- Branson, R.L., Schulbach, R.S. Rauchkolb and J.M. Rible,** 1981. Aplication of chemicals through drip systems. In: Fereres, E., Drip Irrigation Management, Dif of Agrik.Sci., Univ. of California Davis, pp. 29-32
- Bucks, D.A., F.S Nakayman and A.W. Warrick,** 1982. Princioles, practices, and potentialities of trickale (drip) irrigation. In: Hillel, D., Advances in Irrigation 1:219-298
- Frecman, B., E. Carzoli,** 1980, Localized Irrigation FAO, Irrigation and Drainage Paper, №36, p.56

WATER PURIFICATION PRICE AND ACTUALITY OF THE PROBLEM OF WATER DEPURATION OF THE DNIEPER ACCORDING TO THE THEORY OF SOCIAL WELFARE

PhD Stud. Holiachuk O.

National University of Life and Environmental Sciences of Ukraine – Kyiv, Ukraine

E-mail: olha.holiachuk@gmail.com

Abstract. In this article we wish to evaluate efficiency of use of Dnieper cascade hydropower plants on the basis of common approaches to environmental management. We evaluate the efficiency of use of the flooded areas of the hydropower station in agriculture. Dnieper reservoirs ranking on the degree of energy risk (the possibility of man-made tsunami generation) was made. There are some water depuration problem mentioned and ways to solve problem of water depuration in Dnieper river. Also in the article we want to present analysis of water depuration systems in European countries.

KEYWORDS: WATER DEPURATION, HYDROPOWER PLANTS, RENEABLE ENERGETIC, SOCIAL WELFARE

1. Introduction

Before the era of nuclear power, contribution of hydropower in the energy balance of the former Soviet Union was considered indisputable. Thus the negative effects, associated with the creation of reservoirs on the plains, were not taken into account e.g. flooding of large areas, destruction of towns and historic monuments, increase of the risk of man-made disasters. But time passed and in 1970s in Ukraine were built several nuclear power plants and as a result appeared the need to develop solar, wind and bioenergy and it led to decrease of the share of electricity generation by hydropower

plants to 5-7%. Over the past decade, the agricultural sector of the Ukrainian economy has become one of the major players in the global food market and agricultural export of the country has become one of the landmarks of the national economic development. That is why there is an urgent need to use territory of the cascade of Dnieper reservoirs for agricultural purpose. However, beside inappropriate use of land resources [1,2,6] and deterioration of the quality of water resources there is a high risk of man-made disasters which can be caused by the functioning of the Dnieper cascade hydropower plants.

Table 1 The price of water and electricity in European countries

Country	Water tariff, euro per cubic meter	Water fee, euro per month	Electricity tariff, euro cents per kWh	Electricity fee, euro per month	The average city fee for water treatment, euros per month
Belgium	2,92	44,968	28	50,736	20
Denmark	5,63	86,702	30	54,36	27
Germany	5,09	78,386	30	54,36	32
France	3,1	47,74	17	30,804	31
Great Britain	2,3	35,42	18	32,616	25
Sweden	3,05	46,97	19	34,428	26

*average water consumption – 15,4 cubic meter, average electricity consumption – 181,2 kWh

**[Source: Eurostat, January 2018] –[3]

2. Prerequisites and means for solving the problem

The problem of water pollution is directly caused by significant masses of stagnant water of the Dnieper. This also directly affects the generation of electricity by cascade power plants. In our view, reducing hydropower volumes is not a random factor, but rather a factor that can be explained by the wear of equipment for power plants that has been operating for a long period of time. Therefore, without proper upgrading of power plants and associated infrastructure (gateways, dams of reservoirs), hydroelectricity production will decrease. At the same time, the risks of technogenic disasters continue to increase as a result of the further exploitation of the Dnieper hydroelectric power stations. At the same time, the efficiency of renewable energy is increasing. In the first place, the advantages of the energy industry should include a small negative impact on the state of the environment: for example, in Ukraine there are significant areas of unproductive

- Physical - screening, sedimentation and flushing, aeration, filtration
- Chemical - chlorine (an oxidizing chemical commonly used to destroy bacteria that break down water by adding

and untreated land where solar enrichment is possible. With regard to the use of wind energy, due to the small areas that are withdrawn from agrarian use, negative external effects, as the European experience shows, are associated with the possibility of an obstacle to seasonal migration of birds. Therefore, this factor must be taken into account when choosing places for rising wind turbines.[3]

In recent years, significant growth rates of growth have been observed in Ukraine due to renewed sources. Represent the trends observed in hydropower and renewable energy in the form of exponential trends.

3. Solution of the examined problem

Today one of the most pressing topics is the problem of water treatment.

Water purification is the process of filtration and purification of water from pollutants and chemicals.

Water purification processes can be divided into 4 groups:

contaminants), ozone, neutralization (a method that adds acid or a base to bring water to its natural pH)

- Biological - aerobic processes (bacteria decompose organic matter and convert it into carbon dioxide that can be used

by plants; oxygen is used in this process), anaerobic processes (fermentation is used for fermentation of waste at a certain temperature), composting (type of aerobic process where waste water processed by mixing with sawdust or other carbon sources)

- Sediment treatment (process of separation into solids and liquids, where the lowest possible residual moisture is required in the solid phase and the lowest solids residues are required in the separated liquid phase) [8]

The process of water purification, usually occurs in the following sequence [9]:

- 1) the wastewater is temporarily held in a sump where heavier solids sink to the bottom and lighter solids float to the surface. After filtration, these materials are retained until the purified liquid is discharged or moved to a more severe secondary wastewater treatment phase;

- 2) further, sewage treatment operates at a deeper level than the primary one and is designed to significantly reduce the biological content of the waste through aerobic biological processes (biofiltration, aeration, oxidation rates);

- 3) improving water quality to domestic and industry standards, or meeting specific requirements for safe water discharge. In the case of municipal water, the removal of pathogens is envisaged to ensure the safety of water for drinking purposes.

Of course, the best result is a complex of all the above processes. In Ukraine, chemical treatment is used for river and waste water. This occurs in the chemical water saturation unit after several hours of settling for water. The main disinfectant is chlorine. The main goal of Ukrainian water treatment plants is to ensure the safety of water that gets into the taps of consumers, but not to bring it to a transparent color and to eliminate odor.

All water utilities in the country supply a little more than 3.8 billion cubic meters. m of water per year. Of these, a third - 1.1 billion cubic meters. m - flows from the system in an unknown direction. That is, it is stolen, evaporated, seeped through holes and cracks in the pipes. Half of the losses are in chronic non-payment. In the top three - Lugansk, Donetsk and Kharkiv regions. In each of them the debt of the population and the enterprises to the water and sewerage organizations is accounted for by billions of hryvnias. [10]

By October 2018, industry losses exceeded UAH 6.5 billion, which is approximately 2% of Ukraine's GDP.

Of the 180,000 km of water-flowing pipes in homes, establishments and businesses, 69,000 km require immediate reconstruction. This means that a pipeline that is half the length of the earth's equator is required for replacement.

The life of such wells is 15 years. In fact, many are over 40. There is no penny to replace them, since there has been no depreciation line in the tariff for all the years of Ukrainian independence.

According to UkrVodoKanal (government organization), in order for the critical situation not to turn into a hopeless one, in the next ten years, it will be necessary to invest \$ 19.5 billion in retrofitting and, in essence, in the patching of the industry.

Well, to bring it to the European level, will have to invest \$ 40 billion.

The Dnieper basin area within Ukraine is more than 290 thousand square kilometers. About 70% of the country's population uses the Dnieper water.

The poor condition of the river is not just a problem for people living on its banks. This is a national security issue and a strategic freshwater supply for Ukraine. That is why returning to a healthy state of the Dnieper should be a nationwide task.

Taking into account the experience of the European countries for the purification of the Rhine, it is worth noting the coordinated and systematic work of the governments of all the participating countries. [1,10]

In Germany, for example, one of the most serious standards for centralized water supply. The latest filters and quality control system allow you to drink water directly from the tap. Moreover, they do not use chlorine (except in extreme cases), and residents can check individual water parameters via the Internet.

Just a small part of countries with their nowadays example of water price policies are presented in Table 1.

A similar approach is used in France, Spain, England, Belgium and other leading states of the EU. The government is tightly controlling the emissions of businesses, so the work for wastewater treatment plants is several times less. Other freshwater sources, such as wells or mountain reservoirs, may also be regional, but the main focus is on filtering public water.

Austria, Switzerland and Luxembourg can easily rest on mountain rivers and lakes. Conservation of the natural environment in the Alps allows the use of fluid with minimal human impact. Inhabitants of the region can, without reproach, consume water banal in the kitchen and offer tourists as an alpine natural.

Scandinavians are also to some extent lucky, because low average temperatures hinder the spread of viruses and bacteria in normal reservoirs. The permafrost (which is one of the main stocks of fresh H₂ O in general), fjords and high waterfalls allow you not to invest too much in the preparation of water for centralized supply. Particular attention is paid to Finland - the highest requirements are imposed even on pure natural sources.

However, not all EU countries can boast this level of water quality. Romania, Turkey, Bulgaria, Croatia and a number of other countries make it possible for companies to sell treated water and filtration systems. [10]

Today the process of water treatment of the Dnieper River has been intensified in Ukraine and the first step was the allocation of funds for the construction of a water treatment plant near Kiev. 500,000 euros have been earmarked for construction.

4. Results and discussion

All possible losses connected with functioning of reservoirs are not limited to the wastage of flooded areas. The general scheme of the risks evaluation of further functioning of reservoirs is presented in Figure 1. They can be divided into three groups: economic, technological and environmental.

We made an attempt to assess the expected total annual losses

$\bar{L}$ which consist of economical - L_{ek} ; ecological - L_{ekol} ; and technological - L_t :

$$\bar{L} = L_{ek} + L_{ekol} + L_t \quad (1)$$

In the first approximation economic losses are equal to the difference between the price of potential agricultural products V_{ap}

and the value of producing electric energy V_e :

$$L_{ek} = V_{ap} - V_e \quad (2)$$

Environmental risk in a first approximation must be evaluated on the basis of cost of measures aimed to bring the mass of water in the reservoir (with absence of flow) to state of the river water [4,5,7].

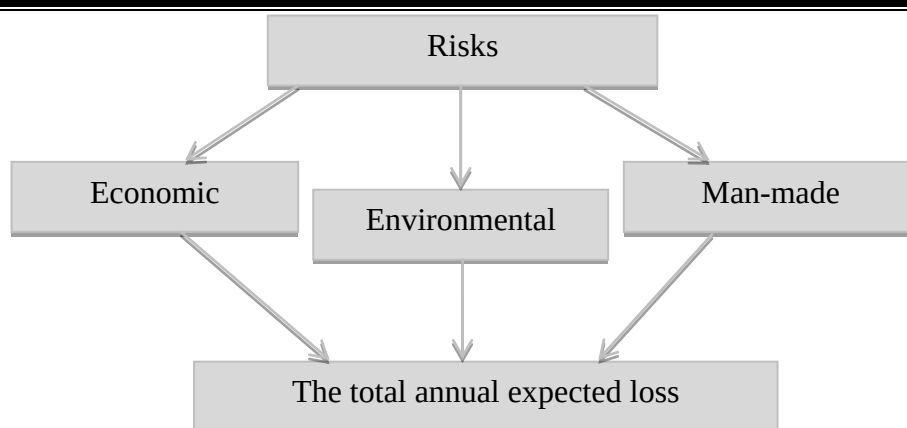


Fig. 1. Model of possible risks of functioning of Dnieper reservoirs

5. Conclusion

We propose a complex approach to risk assessment of use of the Dnieper cascade hydropower station. We use a stochastic method of assessment of potential losses connected with the use of Dnieper reservoirs in order to assess the losses, which can be caused by violation of the integrity of the dam. We evaluated the potential losses of man-made tsunami for Kyiv reservoir. In the

research was made evaluation of the potential hazards of each of the Dnieper reservoirs which can be caused by man-made tsunami. On the basis of the achieved results we ranked the reservoirs according to the degree of economic insecurity. As we have already emphasized, social losses consist of economic, environmental and technogenic (Table 2).

Table 2 Losses from further use of the Dnipro hydroelectric power station cascade

Economic		Man-made		Environmental	
Type of loss	Volume and its error	Type of loss	Volume and its error	Type of loss	Volume and its error
No use of the Dnipro transport potential	$E(x_1) = 550$; $\sigma_1 = 165$	Loss of man-made tsunami likely due to disruption of reservoir dams	$E(x_3) = 0,3$ $\sigma_3 = 31$	Deterioration of drinking water quality	Affects water supply for 6.5 million people
Alternative (agricultural) use	$E(x_2) = 250$ $\sigma_2 = 25$	Support for dams and reservoir safety	No information	Deterioration of the recreational potential of the coastal zone	Reduces recreational opportunities for 6.43 million people close to home. Additional costs for transportation to the place of rest - UAH 5-10 billion.
				Quantitative and qualitative reduction of fishery resources	It has a negative impact on the dependence on imports of fishery products

*Own calculations

Economic losses have already been partially estimated on the basis of alternative (agrarian) use of flooded areas and are at the level of mathematical expectation of USD 250 million with a 10% error due to variability in production volumes and prices. Transformation of the of the key symbol of the Ukrainian state of rapid flow into the system of stagnated reservoirs has no economic reasons taking into account that hydropower stations produce only 5% of the electricity of the total amount and the flooded areas can be used more efficiently. are more effectively use the flooded areas.

6. Literature:

- Veklych O. Ekologichna cina ekonomichnogo zrostantnya Ukrainy. Ekonomika Ukrainy. 2012. Issue 1.P. 51—60. (Ukr)
- Pigou A. Ekonomicheskaya teoriya blagosostoyaniya, Russia: English translation.-Moscow: Progress, 1985.— 511 p.(Rus)
- Electronic resource Electricity price statistics https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics#Electricity_prices_for_household_consumers
- Coase Ronald The Problem of Social Cost, Journal of Law and Economics, 1960, Vol. 3, No. 1, pp. 1–44.
- Maidment D.R. Handbook of Hidrology. NewYork.-1992.-Grow-Fill Inc.432 pp.
- Muller, Richard A. . "Chapter 1. Energy, Power, and Explosions". Physics for Future Presidents, a text book. ISBN978-1426624599, 2001–2002
- Samuelson, Paul A. "Diagrammatic Exposition of a Theory of Public Expenditure," The Review of Economics and Statistics,1955, Vol. 37, No. 4, pp. 350–56.
- Electronic resource Four Effective Processes to Treat Wastewater <https://eponline.com/Articles/2018/02/08/Four-Effective-Processes-to-Treat-Wastewater.aspx?m=1&Page=2>
- Electronic resource What Are the Three Stages of Wastewater Treatment? <https://www.arviatechnology.com/what-are-the-three-stages-of-wastewater-treatment/>
- Electronic resource Yak vody napytys' <https://magazine.nv.ua/ukr/journal/3317-journal-no-45/jak-piti-dati.html> (Ukr)

ASSESSMENT OF SOIL CARBON STORAGE IN SAXAUL FORESTS IN THE BUIN ZAHRA DESERT OF IRAN.

Naseri H.R., PhD.¹, Shakeri R., PhD.², Yousefi Khanghah S., PhD.², Pour Rezaee J., PhD.²
 International Desert Research Center, University of Tehran, Iran ¹
 Khatam-o- Alania industrial University of Behbahan, Iran²

hnrnaseri@ut.ac.ir

Abstract- Deserts cover about one-fifth of the Earth's surface and most of them have a considerable amount of specialized vegetation which is important for soil conservation. Two species of Saxaul (*Haloxylon ammodendron* and *Haloxylon aphyllum*) are the dominant plants in the vast deserts of Iran and both of them are the major plants for afforestation in the desert area. Due to the large area of land planted with Saxaul, the importance of these lands as carbon storage, become more and more. This study carried out in Boeen Zahra desert region of Iran in order to evaluate carbon storage in Saxaul Forests. Study area is located in the south of Qazvin province. Sampling was done in Saxaul (*Haloxylon aphyllum*) stands and the native vegetation of adjacent area (Control area). In both areas, the amounts of aboveground and underground biomass of the species were calculated by cutting and weighing the aerial parts (leaves, stem), roots, and soil Sampling was carried out to a depth of 30 cm. The comparison of the carbon content of *H. aphyllum* in the unit of the measuring surface and control areas showed the difference of this ability between two areas. ($p < 0.01$). The results indicated that the total soil carbon content of *H. aphyllum* (1453.2 kg/ha) was significantly ($p < 0.01$) more than the control area (314.3 kg/ha).

Keywords: HALOXYLON APHYLLUM, DESERT VAGATATION, ORGANIC CARBON, IRAN

1. Introduction

The world's drylands, 6.31 billion hectares (Bha) or 47% of the earth's land area, are found in a wide range of climates spanning from hot to cold (Lal, 2001). Although deserts and so-called dryland habitats are indeed largely waterless and parched, they are able to support a great variety of life. Most deserts have a considerable amount of specialized vegetation, which is important for soil conservation and herbivores. Canopy in most deserts is very rare and plants are mainly ground-hugging shrubs and short woody trees. As these types of plants grow, they sequester carbon in their tissues, and as the amount of tree biomass increases, the increase in atmospheric CO₂ is mitigated. Nowadays, there is much concern that the increasing concentration of greenhouse gases (GHGs) in general, and carbon dioxide in particular, in the atmosphere contributes to global warming by trapping long-wave radiation reflected from the surface of the earth Carbon sequestration, i.e. capturing and securing carbon that would otherwise be emitted and remain in the atmosphere might be a suitable alternative to control atmospheric emission of carbon (Kumar *et al.*, 2009) There is a strong link between desertification of the drylands and emission of CO₂ from soil and vegetation to the atmosphere (Lal, 2001). Planning at a scale of conservation reserves aims to maintain or improve the ecological condition of the targeted biological or environmental feature of these areas or mitigate the threats to them (Groves *et al.* 2002). In some part of Iranian Desert, vegetation is suffering from livestock overgrazing, mining development, road construction, and other human activities. Two species of Saxaul (*Haloxylon ammodendron* and *Haloxylon aphyllum*) are the dominant plants in the vast deserts of Iran and both of them are the dominant plant for afforestation in the desert area. Besides functioning as a C-sink, the vegetation of the Iranian Desert and semi-deserts takes on a multi-functional key role in offering additional benefits to the ecosystem. Afforestation in desert regions is one of the most practical and advantageous methods of desert management. The carbon stock of the Saxaul vegetation is low compared to other ecosystems of the Iran, but restoration and conservation of Saxaul vegetation is one way to sequester carbon through vegetation for Iran, which do not have much other woody vegetation. Nowadays Due to the large area of land planted with Saxaul, the importance of these lands as carbon storage, become more. The purpose of this study is to evaluate carbon storage in Saxaul stand in the desert area of Iran.

2. Materials and Methods

2.1 Study Area

The study area (35°44'04"N 50°11'00"E, 35°45'05"N 50°13'17"E) covered 339 ha of (237 ha *Haloxylon aphyllum* and 102 ha control area) Buin Zahra plain. This area is a desert region with a temporal saline river (Rud- e- Shor in Persian) located in the south of Qazvin province near by Buin Zahra city (Figure 1). The mean annual temperature and mean annual rainfall during 1995-2015 were 17.4°C and 210 mm. This region has the arid and desert climatic condition and almost 70% to 80% of the annual precipitation is concentrated in the months from September to March, while less than 5% occurs in the summer. The average elevation of study area is roughly 1100 meters above sea level. Much of study area covered by native halophyte, e.g., *Halocnemum strobilaceum* M.B. and non-halophyte species *Artemisia sieberi* Besser. Some Part of the studied area has been planted with Saxaul trees. It has been a program to combat desertification during the three past decades.

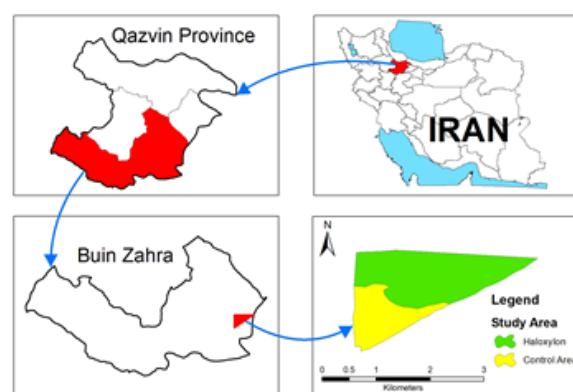


Fig. 1 Geographical position of study area in Qazvin province of Iran

2.2 Methods

For soil and plant sampling, study sites were established in the desert region of Buin Zahra in an area planted with *Haloxylon aphyllum* (Minkw.) Iljin, as well as adjacent native vegetation (control area) (Fig. 2). The age of the *H. aphyllum* stand in the study area is about 35 years. This stand is used as a park for local live

grazes weekend by people but native vegetation (control area) stock e.g. Camels and sheep. Totally 90 quadrants (2m × 2m) in the *H. aphyllum* stand and control area were established along ten 500m transects which were selected randomly. All plant and soil samples were collected within these plots. For both sites, the amounts of aboveground and underground biomass of the species were calculated by cutting and weighing the aerial parts (leaves, stem) and roots with 30 repetitions. Regarding the goal of the study, effective depth for root sampling in *H. aphyllum* stand and control area was 30 cm. Following Rayment and Higginson (1992), the ash method was used to determine the carbon sequestration coefficient of the studied species. Soil sampling was conducted randomly at each site. For each of the selected sites representing vegetation type, 30 sampling ditches were dug. Soil bulk density was determined using a soil corer. 30 soil samples at each site were taken and Soil organic carbon (SOC) was measured using Walkley and Black's method (Nelson and Sommers, 1982). In order to determine the amount of sequestered carbon by the gram per square meter, Formula (1) was employed: $Cc = 1000.C (\%) . Bd.e. (1)$

In this formula, Cc refers to the amount of sequestered carbon weight per square meter. C signifies the percentage of the accumulated carbon in the calculated depth of soil. Bd represents the bulk density of the soil and e denotes the thickness of the soil depth by the centimeter. Total system carbon was defined as the sum of the woody biomass, herbaceous biomass, root and litter and soil carbon. All data were analyzed using the SPSS version 16 for Windows software package. Means of carbon stock in different parts were conducted by paired-samples T test.

3. Results and Conclusion

The comparison of the carbon content of *H. aphyllum* in the unit of the measuring surface and control areas (table 1) showed the difference of this ability between two areas ($p < 0.01$). The results indicated that the total soil carbon content of *H. aphyllum* (1453.2 kg/ha) was significantly ($p < 0.01$) more than the control area (314.3 kg/ha). While the amount of carbon stored in the plant for both forested areas and the control area is 35% and 11.2% respectively, much of the organic carbon is stored in the soil in both areas. According to the results; the *H. aphyllum* stand presented significantly higher carbon storage compared to the adjacent control area.

Table 1: Carbon distribution (kg/ha) between the *H. aphyllum* stand and the control area

Parts of C storage	<i>H. aphyllum</i> stand kg/ha	Control area kg/ha	T
Arial parts	279.7	12.3	2.29*
Roots	228.8	22.9	2.36*
SOC	1453.2	314.3	2.60*
Total	1961.7	349.5	2.36*

* :significant: <0.01

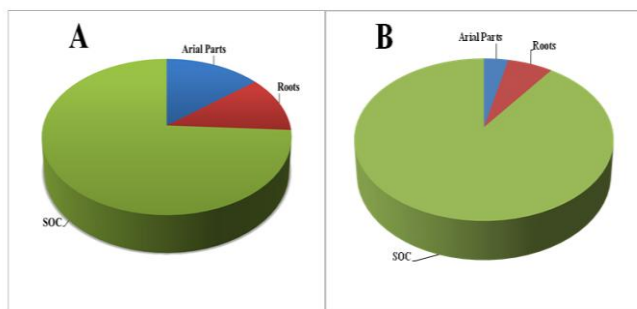


Fig. 2 Carbon ratio in the *H. aphyllum* stand (A) and the adjacent control area (B)

This study clearly demonstrated that tree planting in the study area showed potential for sequestering atmospheric carbon. The establishment of *H. aphyllum* in the Buin Zahra region increased the total ecosystem carbon stocks, primarily as a result of plants' carbon components, particularly the Aerial parts and roots. Hu et al. (2008) reported the same results from the afforestation of semi-arid sandy soil in southeast Keerqin. Biomass productivity in drylands is limited by lack of water and plant nutrients. Therefore, an important strategy lies in growing xerophytic plants and adopting techniques that enhance water and nutrient use efficiencies and improve biomass productivity (Lal, 2001). Growing salt-tolerant (halophytic) plants can improve above- and below-ground biomass production and increase SOC content. Singh (1989) observed that among several fuelwood species evaluated, *Prosopis juliflora* was most adapted to alkaline soils and produced the most biomass, meanwhile, soils of study area belong to Aridisol it seems afforestation by *H. aphyllum* can improve total biomass and help to increase of carbon sequestration process. Changes in carbon pools following the planting of tree were mainly due to plant biomass and litter increases. The average carbon sequestration rate among trees planting that we observed (1961.7 kg/ha) matched observations from other afforested systems in semi-arid regions (Grunzweig et al., 2003) and evidenced the potential of vegetation. However, there were differences in total organic carbon distribution in soil and plants between the control and planted area. Nonetheless, plants were the main facilitators of carbon storage. Schlesinger and Lichter (2001) argued that living wood is the dominant sink for atmospheric CO₂ within regrowth forests; consequently, in arid and semi- arid rangelands, this function belongs to some plants that have sufficient woody stems and roots for reserving carbon.

4. References

- Groves, C.R. et al., 2002. Biodiversity Conservation: Putting into for Planning. Bioscience, 52(6), pp.499–512.
- Grünzweig, J. M., Lin, T., Rotenberg, E., Schwartz, A., & Yakir, D. (2003). Carbon sequestration in arid- land forest. *Global Change Biology*, 9(5), 791-799.
- Hu, Y. L., Zeng, D. H., Fan, Z. P., Chen, G. S., Zhao, Q., & Pepper, D. (2008). Changes in ecosystem carbon stocks following grassland afforestation of semiarid sandy soil in the southeastern Keerqin Sandy Lands, China. *Journal of Arid Environments*, 72(12), 2193-2200.
- Kumar, G. P., Murkute, A. A., Gupta, S., & Singh, S. B. (2009). Carbon sequestration with special reference to agroforestry in cold deserts of Ladakh. *Current Science*, 1063-1068.
- Lal, R. (2001). Potential of desertification control to sequester carbon and mitigate the greenhouse effect. *Climatic change*, 51(1), 35-72.
- Nelson, D. W., & Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. *Methods of soil analysis part 3— chemical methods, (methodsofsoilan3)*, 961-1010.
- Rayment, G. E., & Higginson, F. R. (1992). Australian laboratory handbook of soil and water chemical methods. Inkata Press Pty Ltd.
- Singh, B.: 1989, 'Rehabilitation of Alkaline Wasteland on the Gangetic Alluvial Plains of Uttar Pradesh, India, through Afforestation', *Land Degrad. Rehab.* 1, 305–310.
- Schlesinger, W. H., & Lichter, J. (2001). Limited carbon storage in soil and litter of experimental forest plots under increased atmospheric CO₂. *Nature*, 411(6836), 466.