ISSN: 2490-3442

UNIVERSITY OF EAST SARAJEVO
FACULTY OF AGRICULTURE

Agrofor

AGROFOR International Journal

AGROFOR International Journal, Vol. 5, Issue No. 2, 2020

agrofor.ues.rs.ba

AGROFOR International Journal

PUBLISHER
University of East Sarajevo, Faculty of Agriculture
Vuka Karadzica 30, 71123 East Sarajevo, Bosnia and Herzegovina
Telephone/fax: +387 57 340 401; +387 57 342 701
Web: agrofor.ues.rs.ba; Email: agroforjournal@gmail.com

Frequency: 3 times per year
Number of copies: 300
ISSN 2490-3434 (Printed)
ISSN 2490-3442 (Online)

CONTENT

Review paper
10.7251/AGRENG2002005F
UDC 502/504

ADOPTION OF WATER AND SOIL CONSERVATION PRACTICES: THEORETICAL FRAMEWORKS AND ATTITUDINAL COMPONENTS

Amirali FARIDI[1], Mohammad KAVOOSI KALASHAMI[1*], Hamid EL BILALI[2]

[1]Department of Agricultural Economics, Faculty of Agricultural Sciences, University of Guilan, Rasht, Iran
[2]International Centre for Advanced Mediterranean Agronomic Studies of Bari (CIHEAM-Bari), Valenzano (Bari), Italy
*Corresponding author: mkavoosi@guilan.ac.ir

ABSTRACT

Agricultural production requires two main resources; water, as a source of life, and soil, as a living environment. Water and soil conservation is a critical issue in areas facing water and soil resource constraints. The purpose of this review paper is to provide an overview on the theoretical frameworks used in the analysis of the adoption of water and soil conservation practices. Different models and frameworks have been used in the analysis of the acceptance and/or adoption of new technologies and practices; these include Technology acceptance model, Motivational model, Theory of reasoned action, theory of planned behavior, Innovation diffusion theory and the Unified theory of acceptance and use of technology. The Icek Ajzen's Theory of Planned Behavior (TPB) has been used as a conceptual framework in many studies on the factors affecting the adoption of water and soil conservation practices. The TPB allows examining the impact of individual factors (i.e. attitude), social norms (cf. subjective norms) and situational factors (i.e. perceived behavioral control) on the adoption of practices. It posits that if a person assesses the suggested behavior as positive (cf. attitude) and if he/she thinks that others want them to perform the behavior (cf. subjective norm), these result in a higher intention and motivation to do so. However, the TPB has some limitations such as not considering environmental/contextual and economic factors that may affect the individual's intention to perform a behavior. Therefore, despite the widespread use of the TPB model, the paper concludes that the UTAUT seems a better model in understanding the dynamics of acceptance and adoption of water and soil conservation practices.

Keywords: *Theory of Planned Behavior, Unified Theory of Acceptance and Use of Technology, Technology Adoption, Water conservation, Soil conservation.*

INTRODUCTION

The destruction of agricultural land leads to the loss of soil quality and, consequently, its productivity. Erosion is a major driver of agricultural land degradation and can be very important because it is often irreversible and, in cases of severe degradation, causes complete loss of soil (Hugo, 2006). Soil erosion is a challenging issue not only because it reduces productivity, but also because it is strongly linked to desertification and rural poverty (Barbier & Bishop, 1995). The causes of agricultural land degradation are varied and complex and can be classified into three main categories (Muchena et al., 2005): (1) climate (such as rainfall, drought); (2) bio-geophysics (such as slope, soil type); and (3) Management (such as farmers' education, experience, access to development services). These three groups of variables are crucial in determining the probability and rate of soil erosion (Muchena et al., 2005).

Irrigation water plays an important role in agricultural productivity and food security, but it is becoming a resource whose scarcity is increasing (Bruinsma, 2009). In areas where rainfall is falling, the agricultural sector is facing increased competition with other uses (e.g. houses, industry, power plants). Therefore, the agricultural sector needs to produce more food with less water.

In view of the above-mentioned factors, it is important to consider soil and water conservation practices. In this regard, understanding the challenges surrounding the adoption of these practices by farmers and determining the contribution of economic, social, financial, human and user characteristics to the acceptance process is crucial. Also, understanding the factors affecting the acceptance of conservation practices by farmers can provide insights for appropriate policy and long-term planning. In other words, identifying the factors affecting the adoption of conservation practices is a path for policymakers and planners to reach the micro and macro goals in all social, economic, and so forth fields. Many conceptual models have been used in the study of the adoption or acceptance of new technologies and practices and this study introduces and compares them.

ADOPTION THEORETICAL FRAMEWORKS

Technology acceptance model (TAM)

The Technology Acceptance Model, first proposed by Davis (1985), comprises the core variables of user motivation (i.e., perceived ease of use, perceived usefulness, and attitudes toward technology) and outcome variables (i.e., behavioral intentions, technology use). Of these variables, perceived usefulness (PU) and perceived ease of use (PEU) are considered key variables that directly or indirectly explain the outcomes (Marangunić & Granić, 2015). These variables are often accompanied by external variables explaining variation in perceived usefulness and ease of use; among others, subjective norms (SN), self-efficacy (CSE), and facilitating conditions (FC) were significantly related to the TAM core variables—however, to different degrees (Abdullah & Ward, 2016; Schepers & Wetzels, 2007). These external variables represent personal capabilities next to contextual factors and their conceptualizations vary across studies. Overall, perceived ease of use and

perceived usefulness, the most important factors in the TAM, refer to the degrees to which a person believes that using a technology would be free from effort (cf. PEU) and that using a technology would enhance their job or task performance (cf. PU). Since many technology adoption studies have used this model, it can also be used to study the adoption of soil and water conservation measures.

Motivational Model (MM)

Since 1940's, many theories have been developed from motivation research. Self-Determination Theory (SDT) developed by Deci & Ryan (1985) is one of them. SDT proposed that self-determination is a human quality that involves the experience of choice, having choices and making choices (Deci & Ryan, 1985). Deci at al. (1991) mentioned that the regulatory process is choice when behavior is self-determined, but when it is controlled, the regulatory process is compliance or defiance in some cases. The motivation theory has supported the researches in psychology as an explanation for behavior. These researches showed that the motivational theory contains two major factors of motivations: extrinsic motivation and intrinsic motivation. SDT represents the extrinsic motivation and consists of four types of self-determinations (external, interjected, identified and integrated form of regulation), while the intrinsic motivation refers to intrinsic regulation. It also represents how the social environment influences on motivated behaviors. In addition to that, the amotivation behavior must be considered to understand human behavior fully (Deci & Ryan, 1985). Amotivation behavior is non-regulation and not extrinsically or intrinsically motivated.

Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) is one of the earliest technology acceptance theories. It was developed in the field of social psychology by Ajzen and Fishbein in 1975. Its history returns to the period from 1910's to 1960s. This period was the beginning of studying the individuals' behavior through the impact of attitude. Attitude has either a direct or an indirect effect on behavior, and it is either one-dimensional or multidimensional factor. Ajzen and Fishbein (1980) mentioned that TRA was designed to explain virtually any human behavior. TRA is a general model, not designed for a specific behavior or technology but one of the most fundamental theories of human behavior. Ajzen and Fishbein's model was a result of a research program that started in the late of 1950s on the Persuasion Models of Psychology. Their aim was to develop a theory that could predict, explain, and influence human behavior (Ajzen and Fishbein, 1980). They considered that this theory is moderated by two main constructs; attitude toward behavior and subjective norm.

Theory of Planned Behavior (TPB)

An alternative approach to understanding consumer decision making is provided by the Theory of Planned Behavior (Ajzen, 1991, 2005, 2012). Instead of relying on the overall evaluation or utility of a product or service, this theory focuses on the

specific consumer behavior of interest. The goal of the TPB is to provide a comprehensive framework for understanding the determinants of such behaviors. First described in 1985 (Ajzen, 1985), the TPB is today one of the most popular social psychological models for understanding and predicting human behavior. Briefly, in the TPB, the immediate antecedent of a particular behavior is the "intention" to perform the behavior in question. This intention is assumed to be determined by three kinds of considerations or beliefs. The first is termed "behavioral beliefs" and refers to the perceived positive or negative consequences of performing the behavior and the subjective values or evaluations of these consequences. In their aggregate, behavioral beliefs that are readily accessible in memory lead to the formation of a positive or negative "attitude toward the behavior". A second kind of consideration has to do with the perceived expectations and behaviors of important referent individuals or groups, combined with the person's motivation to comply with the referents in question. These considerations are termed 'normative beliefs', and the normative beliefs that are readily accessible in memory combine to produce a perceived social pressure or 'subjective norm' with respect to performing the behavior. The third type of consideration, 'control beliefs', is concerned with the perceived presence of factors that can influence a person's ability to perform the behavior. The third type of consideration, control beliefs, is concerned with the perceived presence of factors that can influence a person's ability to perform the behavior. Together with the perceived power of these factors to facilitate or interfere with behavioral performance, readily accessible control beliefs produce a certain level of perceived behavioral control (or self-efficacy–cf. Bandura, 1977) in relation to the behavior. Wauters et al. (2010) used the TPB in their research on the adoption of soil conservation practices in Belgium. Kumar Chaudhary et al. (2017) used this model too.

Theory of Diffusion of Innovation (TDI)

Diffusion of innovations is a theory by Everett Rogers that seeks to explain how, why, and at what rate new ideas and technologies spread. Rogers argues that diffusion is the process by which an innovation is communicated over time among the participants in a social system. For Rogers (2003), adoption is the decision of "full use of an innovation as the best course of action available" and rejection is the decision of "not to adopt an innovation". Rogers defines diffusion as "the process in which an innovation is communicated through certain channels over time among the members of a social system". As expressed in this definition, innovation, communication channels, time, and social system are the four key components of the diffusion of innovations. Innovation diffusion research has attempted to explain the variables that influence how and why users adopt a new technology such as the Internet; opinion leaders exert influence on audience behavior via their personal contact, but additional intermediaries, called change agents and gatekeepers, are also included in the process of diffusion. Mango et al. (2017) used the theory of diffusion of innovation in a study about awareness and adoption of soil and water conservation practices in the Chinyanja Triangle (Southern Africa).

Unified Theory of Acceptance and Use of Technology (UTAUT)

Venkatesh et al. (2003) developed a unified model that brings together alternative views on user and innovation acceptance viz. the Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT suggests that four core constructs (viz. performance expectancy, effort expectancy, social influence and facilitating conditions) are direct determinants of behavioral intention and ultimately behavior, and that these constructs are, in turn, moderated by gender, age, experience and voluntariness of use (Venkatesh et al., 2003). It is argued that by examining the presence of each of these constructs in a 'real world' environment, researchers and practitioners will be able to assess an individual's intention to use a specific technology/system, thus allowing for the identification of the key influences on acceptance in any given context. In the years since its introduction, UTAUT has been widely employed in technology adoption and diffusion research as a theoretical lens by researchers conducting empirical studies of user intention and behavior. Since the original article by Venkatesh et al. (2003), UTAUT has been discussed with reference to a range of technologies (e.g. information and communication technologies) with different control factors (e.g. age, gender, experience, voluntariness to use, income, and education), and focusing upon a variety of user groups.

DISCUSSION

Each of the presented models has its strengths but also limitations and shortcomings. One of the limitations of the Technology Acceptance Model (TAM) concerns the variable that pertains to the behavior of users, which is inevitably evaluated through subjective means such as behavioral intention (BI) and interpersonal influence. Nevertheless, interpersonal influence, as a subjective norm, means when a person is influenced by words of mouth from a colleague, or a friend. While a superior can influence subordinate employee by directing him/her to perform a specific task with the use of a specific technology, based on the company's policy, a friend has no directive influence over staff who is subject to the line manager. Another limitation is that behavior cannot be reliably quantified in an empirical investigation, owing to a number of different subjective factors such as the norms and values of societies, personal attributes and personality traits. Hence, the argument that a relative or friends could influence the use of a technology through exerting social pressure (Ang et al., 2015; Shan & King, 2015) is highly falsifiable.

The Motivational Model (MM) has many applications on the motivational studies, learning, and health care. But its application on technology usage and acceptance is not effective (Deci & Ryan, 2008; Ryan & Deci, 2000). It still needs to include many factors to become more suitable to study technology usage (Parijat & Bagga, 2014; Gagné & Deci, 2005).

The Theory of Reasoned Action (TRA) is a very general model and not designed for a specific behavior or technology (Davis et al., 1989). Correspondence is the main limitation for it (Ajzen, 1985); it predicts a specific behavior, attitude, and

intention to be in agreement with action, target, context, and time frame (Sheppard et al., 1988; Silva & Dias, 2007). TRA is still limited with no mention to other variables that affect behavioral intention like fear, threat, mood or previous experiences.

The Theory of Planned Behavior (TPB) is an extension to the limited TRA model. It suggests that the behaviors are already planned by adding a new construct that is the perceived behavioral control (Sheppard et al., 1988). However, it does not show the planning mechanism of individuals and how it relates to TPB, with no mention to other variables that affect behavioral intention and motivation, such as fear, threat, mood or past experience. Furthermore, it does not take into account the environmental or economic factors that may influence the individuals' intention to perform a behavior (Truong, 2008).

The Theory of Diffusion of Innovation (TDI) explains the decision of innovation and predicts the rates of its adoption (Askarany et al., 2012; Hameed et al., 2012). But it does not mention how the attitude affects accepting or rejecting a technology (Karahanna et al., 1999; Oliveira & Martins, 2011). In addition, this theory doesn't care about individual's resources or social support to adopt the new behavior.

The Theory of Acceptance and Use of Technology (UTAUT) has been praised for its capability to inform the understanding of factors that determine the acceptance of an impending new technology. Although the model is quite new, its growth and popularity are high as compared to the preceding versions (Al-Hakim, 2006). Moreover, its stability, validity and viability in technology adoption surveys within several contexts have already been ascertained and practically confirmed. For instance, the study of Alshehri et al (2012) on TAM, TRA and TPB ascertained that UTAUT model enlightens the understanding of factors that influence the acceptance of new technologies (Jaeger & Matteson, 2009; Mayer-Schönberger & Lazer, 2007). UTAUT model explains over 70% of all the technology acceptance behavior, unlike other models that explain as little as 40% of the entire technology acceptance behavior. Therefore, UTAUT exposes more factors influencing the intention of the observed behavior (Grant, 2011). Actually, it intends to counter the deficiencies of prior models and theories by combining them together for a common good. For that reason, it has emerged as one of the most encompassing adoption theories (Grant, 2011). Even though this model has attained an adequate reception from most researchers, a number of shortcomings exist. Although the integrated models utilize several terminologies within their phraseology of acceptance, these aspects are often similar in nature. Subsequently, every model has its own shortcomings, which also influences the ultimate viability of UTUAT model as a whole (Cetron, 2007). In particular, UTAUT has limitations mainly in its relationship between the intention and use behavior. Nevertheless, the benefits obtained from this model are far more significant than the shortcomings listed above (Mayer-Schönberger & Lazer, 2007; Grant, 2011).

CONCLUSION

This paper provides an overview on the main conceptual models and theories used in the studies on the adoption of new technologies and practices, namely the Technology Acceptance Model (TAM), the Motivational Model (MM), the Theory of Reasoned Action (TRA), the Theory of Planned Behavior (TPB), the Theory of Diffusion of Innovation (TDI) and the Unified Theory of Acceptance and Use of Technology (UTAUT). It also discusses the main limitations and shortcomings of each model. Since the TAM model focuses primarily on the impact of friends on technology adoption, it cannot be used as a reliable model to study the adoption of water and soil conservation practices. The MM also loses its qualification for use due to the lack of required components and its incompleteness. The TRA is a general model and can be used to analyze the acceptance of water and soil conservation practices and the attitudinal factors that affect it, but it ignores external factors that may be effective. Therefore, despite the relative competence of this model, it cannot be effectively applied. Although TPB is an expanded model of TRA and has been applied in a wide range of studies related to acceptance of soil and water conservation practices, it has some limitations (e.g. lack of relationship between behavioral intention and motivation, not considering environmental and economic factors) that makes it ineffective in predicting use behavior. While the primary focus is on attitudinal factors, the TDI model does not cover how attitudes affect individual decisions regarding the acceptance of protection practices. Therefore, this model also cannot play a significant role in the research on the adoption of soil and water conservation practices. While the UTAUT is a newer, it is more complete and more applicable than the other models, its advantages are far more than its disadvantages and weaknesses, and its competence for application is far greater than the other models that were introduced in this study. Therefore, despite the widespread use of the TPB model, we suggest that researchers studying the adoption of new practices and technologies in agriculture use the UTAUT model.

REFERENCES

Abdullah, F. & Ward, R. (2016). Developing a General Extended Technology Acceptance Model for E-Learning (GETAMEL) by analysing commonly used external factors. Computers in Human Behavior, 56, 238-256. doi:10.1016/j.chb.2015.11.036

Ajzen I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2): 179-211. DOI: 10.1016/0749-5978(91)90020-T

Ajzen I. (2005). Attitudes, personality, and behavior. Maidenhead, UK: Open University Press.

Ajzen I. (2012). The theory of planned behavior. In, Lange P.A.M., Kruglanski A.W. & Higgins E.T. (Eds.), Handbook of theories of social psychology. London, UK: Sage. pp. 438-459.

Ajzen, I. & Fishbein, M. (1980). Understanding attitudes and predicting social behaviour. Englewood Cliffs, N.J.: Prentice-Hall.

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. Action control. Berlin, Heidelberg: Springer. pp. 11-39.

Al-Hakim, L. (2006). Global E-Government: Theory, Applications and Benchmarking: Theory, Applications and Benchmarking. University of Southern Queensland, Australia. DOI: 10.4018/978-1-59904-027-1

Alshehri, M., Drew, S., Alhussain, T. & Alghamdi, R. (2012). The Effects of Website Quality on Adoption of E-Government Service: An Empirical Study Applying UTAUT Model Using SEM. 23rd Australasian Conference on Information Systems, Melbourn, Australia.

Ang, M. C., Ramayah, T. & Amin, H. (2015). A theory of planned behavior perspective on hiring Malaysians with disabilities. Equality, Diversity and Inclusion: An International Journal, 34(3), 186-200.

Askarany, D., Brierley, J. A. & Yazdifar, H. (2012). The effect of innovation characteristics on activity-based costing adoption. Int. J. Managerial and Financial Accounting, 4(3): 291–313.

Barbier, E. B. and Bishop, J. T. (1995). Economic values and incentives affecting soil and water conservation in developing countries. Journal of soil and water conservation 50(2): 133-137.

Bruinsma, J. (2009). The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050. Paper Prepared for the Expert Meeting on How to Feed the World in 2050, Food and Agriculture Organization (FAO), Rome.

Cetron, J. F. (2007). Wireless acceptance in a University setting using the Unified Theory of Acceptance and Use of Technology. University of Delaware: New York.

Davis, F. D. (1985). A technology acceptance model for empirically testing new end-user information systems: Theory and results. PhD, Massachusetts Institute of Technology, Cambridge, MA. Retrieved from https://dspace.mit.edu/bitstream/handle/1721.1/15192/14927137-MIT.pdf?sequence=2

Davis, F. D., Bagozzi, R. P. & Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. Management Science, 35(8), 982-1003.

Deci E. L. and Ryan R. M., (2008). Self-Determination Theory: A macrotheory of Human Motivation, Development, and Health. Can. Psychol. J., 49(3), 182–185.

Deci, E. L. & Ryan, R. (1985). Motivation and self-determination in human behavior. New York: Plenum Publishing Co.

Deci, E. L., Vallerand, R. J., Pelletier, L. G. & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *Educational psychologist*, 26(3&4): 325–346.

Fishbein M. and Ajzen I. (1975). Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research. Addison-Wesley, Libraries Australia.

Gagné, M. & Deci, E. L. (2005). Self-determination theory and work motivation. Journal of Organizational behavior, 26(4), 331-362.

Hameed, M. A., Counsell, S. & Swift, S. (2012). A conceptual model for the process of IT innovation adoption in organizations. Journal of Engineering and Technology Management, 29(3), 358-390.

Hugo, G. (2006). Trends in land degradation in South America. Workshop of Agricultural Meteorology Programme (AgMP). World Meteorological Organization (WMO): Portland, Oregon, pp. 127-146.

Grant, K., (2011). Proceedings of the 2nd International Conference on Information Management and Evaluation. Ryerson University, Toronto (Canada), 27-28 April 2011. Reading: Academic Pub. International Ltd.

Jaeger, P. & Matteson, M. (2009). e-Government and Technology Acceptance: The Case of the Implementation of Section 508 Guidelines for Websites. Electronic Journal of E-Government, 7(1), 87–98.

Karahanna, E., Straub, D. W. & Chervany, N. L. (1999). Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs. MIS quarterly, 23(2), 183-213.

Kumar Chaudhary, A., Warner, L. A., Lamm, A. J., Israel, G. D., Rumble, J. N., & Cantrell, R. A. (2017). Using the Theory of Planned Behavior to Encourage Water Conservation among Extension Clients. Journal of Agricultural Education, 58(3), 185-202.

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. International Soil and Water Conservation Research, 5(2), 122-129.

Marangunić, N. & Granić, A. (2015). Technology acceptance model: a literature review from 1986 to 2013. Universal Access in the Information Society, 14(1), 81-95. DOI:10.1007/s10209-014-0348-1

Mayer-Schönberger, V. & Lazer, D. (2007). From e-government to i-government: Governance and information technology in the 21st century. MIT Press, Belfer Center for Science and International Affairs John F. Kennedy School of Government, Cambridge, Massachusetts.

Muchena, F., Onduru, D., Gachini, G. & De Jager, A. (2005). Turning the tides of soil degradation in Africa: capturing the reality and exploring opportunities. Land Use Policy, 22(1), 23-31.

Oliveira, T., & Martins, M. F. (2011). Literature review of information technology adoption models at firm level. Electronic Journal of Information Systems Evaluation, 14(1), 110-121.

Orr, G. (2003). Diffusion of innovations, by Everett Rogers (1995). Retrieved from http://www.stanford.edu

Parijat, P., & Bagga, S. (2014). Victor Vroom's expectancy theory of motivation–An evaluation. International Research Journal of Business and Management, 7(9), 1-8.

Schepers, J. & Wetzels, M. (2007). A meta-analysis of the technology acceptance model: Investigating subjective norm and moderation effects. Information & Management, 44(1), 90-103. doi:10.1016/j.im.2006.10.007

Shan, Y. & King, K. W. (2015). The effects of interpersonal tie strength and subjective norms on consumers' brand-related eWOM referral intentions. Journal of Interactive Advertising, 15(1), 16-27.

Silva, P. M. & Dias, G. A. (2007). Theories about technology acceptance: why the users accept or reject the information technology? Brazilian Journal of Information Science: Research Trends, 1(2), 69-86.

Truong, Y. (2008). An evaluation of the theory of planned behaviour in consumer acceptance of online video and television services. The Electronic Journal Information Systems Evaluation, 12(2), 177-186.

Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. MIS quarterly, 27, 425-478.

Wauters, E., Bielders, C., Poesen, J., Govers, G., & Mathijs, E. (2010). Adoption of soil conservation practices in Belgium: an examination of the theory of planned behaviour in the agri-environmental domain. Land Use Policy, 27(1), 86-94.

Review paper
10.7251/AGRENG2002015E
UDC 338.43.02(100)

MAINSTREAMING OF THE SUSTAINABLE DEVELOPMENT GOALS IN THE MEDITERRANEAN: INTEGRATION INTO POLICIES AND STRATEGIES

Hamid EL BILALI*, Gianluigi CARDONE, Giovanni OTTOMANO PALMISANO, Francesco BOTTALICO, Roberto CAPONE

International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM-Bari), Valenzano (Bari), Italy
*Corresponding author: elbilali@iamb.it

ABSTRACT

In the context of the implementation of the 2030 Agenda for Sustainable Development, which encompasses the Sustainable Development Goals (SDGs), mainstreaming means the landing of the Agenda at the national and local levels and its integration into development plans and budgets. This review paper casts light on approaches adopted in the Mediterranean countries to incorporate the SDGs into their national development policies, plans and strategies. It draws upon a comprehensive analysis of the Voluntary National Reviews (VNRs) on the implementation of the SDGs submitted by Mediterranean countries from 2016 to 2019. Mediterranean countries have taken concrete measures to map existing policies against each of the SDG-targets in order to identify policy gaps and to mainstream the 2030 Agenda into their legal and policy frameworks. They used different policy instruments and planning frameworks to take up the 2030 Agenda such as national development plans and strategies (e.g. Albania, Algeria, Croatia, Montenegro, Italy, Slovenia, Turkey), vision documents (e.g. Egypt, Malta, Slovenia, Tunisia) and action plans (e.g. Algeria, France, Spain). A few Mediterranean countries (e.g. Cyprus, Greece, Israel, Lebanon and Morocco) did not adopt any integrated policy instrument and opted for the implementation of the SDGs through existing national policies and strategies. The harmonization of national development plans and strategies with the SDGs is a continuous process and needs to be implemented across sectors. The analysis of the VNRs shows that little attention was dedicated to address trade-offs through policy integration. The achievement of the SDGs implies new modes of policy making as well as a better cross-sectoral coordination and harmonisation of policies in Mediterranean countries. Sharing lessons learned and mutual policy learning among Mediterranean countries could help ensuring a step forward from the formal description of legislation in the VNRs.

Keywords: *SDGs, 2030 Agenda for Sustainable Development, Mediterranean basin, integrated policy, policy mainstreaming, policy coordination.*

INTRODUCTION

The 2030 Agenda for Sustainable Development was adopted at the United Nations' Sustainable Development Summit of September 2015 with 17 Sustainable Development Goals (SDGs) at its core (United Nations, 2015). The 2030 Agenda sets out ambitious goals and provides a universal framework for action (Fukuda-Parr et al., 2018; UNDG, 2016; United Nations, 2015). The concept of sustainable development has taken on a richer, wider meaning within the 2030 Agenda by adding to its three core elements (viz. environmental protection, social inclusion, economic growth) five critical dimensions that are at the heart of the Agenda (viz. 5Ps: people, prosperity, planet, partnership and peace). Furthermore, the 2030 Agenda and the SDGs embody the following core principles: universality, leaving no one behind, interconnectedness and indivisibility, inclusiveness and multi-stakeholder partnerships (United Nations, 2015). Therefore, "*the scope and ambition of the Agenda and SDGs require their inclusion in the instruments that define government action, including the national development plans and budgets*" (p. 16) (UN-DESA, 2016). Achieving the SDGs is essentially a political process (Fukuda-Parr et al., 2018) and will require coherent policies and sustained long-term investments (OECD, 2018, 2019; OECD & SDSN, 2019). Indeed, the effective and efficient implementation of the 2030 Agenda requires an integrated approach to sustainable development. In this context, the United Nations System identified three elements for a coherent and effective support to the implementation of the Agenda under the acronym MAPS (Mainstreaming, Acceleration and Policy Support) (UNDG, 2016): *Mainstreaming* refers to the landing of the 2030 Agenda at the national and local levels, integrating it into national sustainable development plans and into budget allocations; *Acceleration* means a better targeting of resources at priority areas while paying attention to synergies and trade-offs across sectors; and *Policy Support* is about making sure that skills and expertise are made available in a cost-effective and timely way. This clearly shows that the mainstreaming process is crucial for the achievement of the SDGs. Therefore, this review paper sheds light on approaches adopted in the Mediterranean countries to incorporate the SDGs into their national development plans, policies and strategies. It also addresses policy coordination and harmonisation processes as well as approaches pursued to tap into the co-benefits of some SDGs and policy actions while minimizing trade-offs. Furthermore, the paper explores the interconnections between policy coherence, on the one side, and governance and coordination mechanisms, on the other side.

METHODS

The methodology used in the present review is similar to that adopted by El Bilali et al. (2019) in their analysis of the institutional and governance arrangements adopted in Mediterranean countries for the implementation of the SDGs. The review covers all 21 Northern, Southern and Eastern Mediterranean countries considered in the Mediterranean Strategy for Sustainable Development (UNEP/MAP, 2005, 2016) viz. Albania, Algeria, Bosnia and Herzegovina, Croatia,

Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Montenegro, Morocco, Palestine, Slovenia, Spain, Syria, Tunisia and Turkey. The paper is based on a desk review of the Voluntary National Reviews (VNRs) of Mediterranean countries (Table 1) and the syntheses of the VNRs submitted in 2016 (UN-DESA, 2016), 2017 (UN-DESA, 2018a), 2018 (UN-DESA, 2018b) and 2019 (UN-DESA, 2019). Insights from the VNRs were complemented with data collected from different academic and expert sources such as the SDG Index and Dashboards (OECD & SDSN, 2019; Sachs et al., 2018, 2019; Sustainable Development Goals Center for Africa & Sustainable Development Solutions Network, 2018) and scholarly literature (e.g. Allen et al., 2018).

Table 1. Voluntary National Reviews of Mediterranean countries considered in the paper.

Mediterranean Country*	VNR submitted in year(s)	Reference
Albania	2018	Council of Ministers - Republic of Albania (2018)
Algeria	2019	Anonymous (2019a)
Bosnia and Herzegovina	2019	Anonymous (2019d)
Croatia	2019	Government of the Republic of Croatia (2019)
Cyprus	2017	Ministry of Foreign Affairs - Cyprus (2017)
Egypt**	2016	Anonymous (2016a)
	2018	Ministry of Planning Monitoring and Administrative Reform - Egypt (2018)
France	2016	Anonymous (2016b)
Greece	2018	General Secretariat of the Government – Greece (2018)
Israel	2019	Anonymous (2019b)
Italy	2017	Italian Ministry for the Environment, Land and Sea (2017)
Lebanon	2018	Anonymous (2018a)
Malta	2018	Anonymous (2018b)
Montenegro	2016	Ministry of Sustainable Development and Tourism – Montenegro (2016)
Morocco	2016	Ministry of Foreign Affairs and Cooperation – Morocco (2016)
Palestine	2018	State of Palestine (2018)
Slovenia	2017	Anonymous (2017)
Spain	2018	Gobierno de España (2018)
Tunisia	2019	République Tunisienne (2019)
Turkey**	2016	Ministry of Development – Turkey (2016)
	2019	Anonymous (2019c)

*No VNRs submitted by Libya and Syria, due to conflicts in both countries.

**Countries that submitted twice their VNR.

Source: Authors' compilation based on data from UN-DESA (2020).

RESULTS AND DISCUSSION

The alignment of the national development plans with the 2030 Agenda was pursued through different actions such as declaring the Agenda as a reference document for the public policy to ensure a 'whole-of-government' approach (Anonymous, 2018c; UN-DESA, 2018a) or that sustainable development is the central organizing principle of the government (UN-DESA, 2018a, 2019). Nevertheless, the harmonization of national development plans and strategies with the SDGs and the 2030 Agenda is a continuous process and needs to be implemented across sectors (Anonymous, 2018c; UN-DESA, 2019). In this context, countries have taken concrete steps to *map existing policies,* strategies and programmes against each of the SDG-targets to identify policy gaps that require further attention in legislation (Anonymous, 2018c; UN-DESA, 2018a). Indeed, some Mediterranean countries (e.g. Albania, Bosnia and Herzegovina, Spain, Tunisia) assessed the alignment of their national policies with the SDGs through the Rapid Integrated Assessment tool developed in the framework of the United Nations' MAPS (UN-DESA, 2019). Allen et al. (2018) put that France, Italy and Slovenia undertook mapping of the policies and took concrete steps for their alignment with the 2030 Agenda. Other Mediterranean countries (e.g. Greece, Israel, Tunisia, Turkey) showcased increased involvement of *parliaments* to ensure the alignment of the national legislation to the Agenda by filling legislative gaps (either by amending existing legislation or promulgating new legislative frameworks) and to advance the implementation of the SDGs (UN-DESA, 2018b, 2019). Furthermore, the process of localisation and contextualisation of the 2030 Agenda entailed sometimes the *prioritisation of the SDGs* depending on the country context, development status and national priorities (Anonymous, 2018c; UN-DESA, 2019). Indeed, some countries have prioritized the SDGs (and/or SDG-targets) that are relevant in the process of accelerating their national development priorities (UN-DESA, 2019).

World countries have used a variety of planning frameworks and policy instruments to take up the 2030 Agenda at the national level such as national development plans, vision documents, plans of action and SDG roadmaps (Anonymous, 2018c; UN-DESA, 2018a). Countries whose national plans predate the SDGs have analysed how existing policies can advance the 2030 Agenda and/or mandated line ministries to spell out how they are contributing to the achievement of the SDGs (UN-DESA, 2018b). In this respect, many countries noted in their VNRs that their existing policy and planning frameworks were flexible enough to accommodate the SDGs (Anonymous, 2018c). An overview on policy instruments and planning frameworks used in Mediterranean countries to mainstream the SDGs is provided in Table 2.

Albania states in its VNR that the implementation of the 2030 Agenda takes part in the context of the National Strategy for Development and Integration (NSDI) and the European integration process. The NSDI is the main policy document outlining the development vision for Albania as a middle-income economy on the path towards its integration in the EU. The VNR of the country highlights that the NSDI

is fully aligned with the 2030 Agenda as all components of NSDI are directly related to the achievement of SDG-targets (Council of Ministers - Republic of Albania, 2018). *Algeria* refers to the integration of the principles of sustainable development in its new constitution (adopted in 2016) as well as its ratification of different international agreements and conventions. Furthermore, SDGs were integrated in different national strategies mainly the National Strategy on Environment and Sustainable Development (SNEDD 2019–2035) and its Action plan (PNAEDD 2019–2022) (Anonymous, 2019a). *Bosnia* considers EU accession and implementation of the Agenda 2030 as complementary and mutually reinforcing processes. Given the particular political system in the country, the operationalisation of the 2030 Agenda takes place at different governance levels. In particular, it is planned to integrate the SDGs in the Federation of Bosnia and Herzegovina Development Strategy 2020–2027, the upcoming Sustainable development strategy 2030 at the Republika Srpska, and the Development Strategy 2020–2027 of Brčko District (Anonymous, 2019d). *Croatia* revealed in its VNR that work in underway to prepare its 2030 National Development Strategy (NDS), which was expected to be adopted in the first half of 2020, in order to serve as a key strategic document that will shape all future public policies and ensure their alignment with the 2030 Agenda (Government of the Republic of Croatia, 2019; UN-DESA, 2019). *Egypt* reported that its 'Sustainable Development Strategy: Egypt's Vision 2030', launched in February 2016, is aligned with the 2030 Agenda both in terms of content and implementation period (UN-DESA, 2016). Furthermore, the Strategy was reflected in the Government program 2016-2018 that was approved by the parliament (Anonymous, 2016a; UN-DESA, 2016). In addition, several ministries have incorporated the SDGs in their medium- and long-term strategies such as the National Strategy for Science and Technology for Sustainable Development 2030, and the Egypt's Education Transformation Program 2030 (Ministry of Planning Monitoring and Administrative Reform - Egypt, 2018; UN-DESA, 2018b). *France* highlights in its VNR the linkages between SDGs and the Paris Climate Agreement. It also underlines how sectoral policies (e.g. energy, employment) contributes to sustainable development as well as its contribution to international cooperation for sustainable development. Furthermore, the country expressed its intent to develop a National Action Plan for the SDGs (Anonymous, 2016b).

In *Italy*, the National Sustainable Development Strategy 2017–2030 (NSDS) is aligned with the 2030 Agenda. The NSDS updates the former Environmental Action Strategy for Sustainable Development and represents a step towards a holistic policy framework that encompasses, besides environment, also social and economic dimensions (Italian Ministry for the Environment Land and Sea, 2017). *Lebanon* highlights in its VNR that sectoral strategies and plans (e.g. National Social Development Strategy; Vision for Stabilization, Growth and Employment) incorporate some of the SDGs but they need to be adapted to the level of SDG-targets (Anonymous, 2018a). In *Malta*, the Sustainable Development Act (2012) establishes a coordinating mechanism for sustainable development policy.

Moreover, the country has been working on the development of a national Vision 2050 that offers guidelines towards long-term sustainable development and a framework for the mainstreaming of the SDGs across all levels of Government. The Vision will be implemented through a national strategy and action plan (Anonymous, 2018b). In *Palestine*, SDGs were integrated in the National Policy Agenda 2017–2022 (NPA), which addresses 75 out of the 169 targets, as well as in different cross-sectorial strategies (State of Palestine, 2018). *Slovenia*'s Development Strategy 2030, which is in line with on the guidelines of Slovenia's Vision 2050, represents the development framework for implementing the 2030 Agenda. The Strategy focuses on ensuring a high quality of life for all through a balanced economic, social, and environmental development (Anonymous, 2017). *Spain* created a High-Level Group (HLG) for inter-ministerial coordination where ministries, Autonomous Communities and local governments are represented (Gobierno de España, 2018). Moreover, it approved in 2018 an Action Plan for the implementation of the 2030 Agenda that promotes public policies' alignment with the SDGs and identifies transformative measures as well as policy levers. The Action plan also establishes budgeting for the SDGs and compulsory SDG impact reports in legislative activity (Gobierno de España, 2018; OECD & SDSN, 2019). One of the main outcomes of the Action Plan is expected to be the adoption of a 2020–2030 Sustainable Development Strategy (Gobierno de España, 2018).*Tunisia* highlighted that 84 targets are covered by the current five-year development plan (*Plan quinquennal de développement 2016–2020*). Moreover, the country launched the development of the Tunisia Vision 2030, which shows its commitment to the integration of the 2030 Agenda and the 2063 African Agenda (République Tunisienne, 2019).

Table 2. Overview on the mainstreaming of SDGs into national development policies, plans and strategies in the Mediterranean countries.

Mediterranean Country*	Title of policy document or planning framework
Albania	National Strategy for Development and Integration 2015–2020 (NSDI)
Algeria	*Stratégie Nationale pour l'Environnement et le Développement Durable* (SNEDD 2019–2035)
Bosnia and Herzegovina	Development Strategy 2020-2027 of the Federation of Bosnia and Herzegovina
Croatia	2030 National Development Strategy (NDS) (2020)
Egypt	Sustainable Development Strategy: Egypt's Vision 2030
France	National Action Plan for the Sustainable Development Goals
Italy	National Sustainable Development Strategy 2017-2030 (NSDS)
Malta	National Vision 2050
Montenegro	National Strategy of Sustainable Development 2030 (NSSD)
Palestine	National Policy Agenda 2017–2022 (NPA)
Slovenia	Development Strategy 2030 & Slovenia's Vision 2050
Spain	Action Plan for the implementation of the 2030 Agenda (2018)
Tunisia	Tunisia Vision 2030

Turkey	11th National Development Plan

* Cyprus, Greece, Israel, Lebanon and Morocco are not reported in the table since they did not mention in their VNRs any overarching, ad-hoc policy document for the implementation of the SDGs.
Source: Authors' elaboration based on VNRs of Mediterranean countries.

As a result of the focus of the institutions in *Cyprus* on tackling the economic and financial crisis, the country formulated no longer term sustainable development strategy. Therefore, Cyprus relies on a combination of national and EU policies and legislation to cover most of the SDGs such as the Action Plan for Growth and the National Reform Programme drafted in the context of Europe 2020 Strategy (Ministry of Foreign Affairs - Cyprus, 2017). *Montenegro* is a further Mediterranean country that did not adopt any integrated policy instrument for the implementation of the 2030 Agenda. In fact, the country opted for the implementation of the SDGs through the National Strategy for Sustainable Development as well as a group of existing policies and strategies (e.g. National Strategy on Climate Change until 2030, Spatial Plan of Montenegro, Program of Economic Reforms, Medium-term program of accession to the European Union) (Ministry of Sustainable Development and Tourism – Montenegro, 2016; UN-DESA, 2016). *Greece* established in 2016 an inter-ministerial co-ordination network for SDGs to support their mainstreaming as well as the integration of the sustainable development paradigm into legislation, policies and strategies (OECD & SDSN, 2019). The incorporation of the SDGs into the national framework takes place, in line with national priorities, into sectoral policies such as the new National Growth Strategy, the National Rural Development Programme (RDP) 2014–2020, and National Operational Programme for Fisheries and the Sea (OPFS) 2014-2020 (General Secretariat of the Government – Greece, 2018). In *Israel*, the parliament (Knesset) has examined ways in which SDG thinking can be incorporated in the process of preparing legislation. SDGs were mainstreamed in different strategies such as the National Climate Change Adaptation Plan, Sustainable Consumption and Production Action Plan 2015–2020, and National Green Growth Strategy (Anonymous, 2019b). Likewise, *Morocco* revealed in its VNR that many of the SDGs are already included in existing sectoral strategies (UN-DESA, 2016). *Turkey* as well has not opted for drafting a separate policy document or action plan for SDGs and chose instead to integrate them into its national development plans. It pointed out a high degree of consistency between the 10th National Development Plan 2014-2018 and the SDGs (Ministry of Development – Turkey, 2016). The SDGs are considered as one of the main inputs to the 11th National Development Plan (Anonymous, 2019c; Ministry of Development – Turkey, 2016; UN-DESA, 2016).

Policy interventions that aim at the achievement of one SDG might negatively affect another area. Therefore, some countries are using overarching, multi-dimensional concepts such as poverty or human rights to address interlinkages between the SDGs (UN-DESA, 2018b). As for *addressing trade-offs* through

policy integration, the analysis of the VNRs revealed that little attention was devoted to tackling this issue. Therefore, there is a wide scope for mutual learning and sharing lessons among governments on how to identify and address trade-offs between sectoral policies as well as development policy options and objectives (UN-DESA, 2018a). Nevertheless, Turkey performed an SDG mapping to identify inter-linkages among SDGs (e.g. synergies, trade-offs, mutual interactions) and interaction level based on country's context (UN-DESA, 2019). In this respect, UN-DESA (2019) argues that many policy interventions do not identify impact scale as well as synergies/trade-offs and points out that policy coherence remains a challenge for many countries. UN-DESA (2019) adds that "*The SDGs represent challenges that require the improvement of existing and the introduction of new, innovative policies and measures*" (p. 16). Furthermore, countries recognize that the implementation of the SDGs requires effective partnerships with a wide range of stakeholders. It also implies addressing capacity constraints, which are often identified as key challenge for local administrations.

A further step in the process of SDGs mainstreaming consists in their integration into sectoral policies and investment plans to ensure adequate financing (Anonymous, 2018c; Sachs et al., 2019). As for *budget allocation*, OECD and SDSN (2019) put that "*Leveraging financing, budget processes and public procurement can help foster policy coherence beyond electoral cycles and embed the 2030 agenda in day-to-day government operations*" (p. 9). Indeed, public procurement is a key instrument that could be used by governments in the implementation of the SDGs (OECD & SDSN, 2019; Sachs et al., 2018). One way to ensure strong functional and operational linkages between the SDGs and national budgets is to use the SDGs (cf. indicators) as performance measures of budget outcomes (UN-DESA, 2019), which makes it easy to track budgetary allocation to SDGs targets as well as to monitor the different sources of funding for the SDGs. Furthermore, Sachs et al. (2019) suggest that "*performance budgeting, spending reviews, Public Private Partnerships (PPPs) are all powerful tools that must all be mobilized to achieve the goals*" (p. 7).

There are many relationships between policy coordination processes, *governance* mechanisms and budget allocation practices. Indeed, generally speaking, countries that opted for the coordination of the implementation of the SGDs by the presidency or the prime minister's office tend to have an overarching, integrated legal and policy framework that deals with sustainable development while those that opted for more 'collegial' implementation by ministries are more likely to just mainstream the SDGs in the existing sectoral policies. Indeed, as UN-DESA (2019) concludes, "*when policymakers work across ministries and sectors, according to several countries, they are better equipped to recognize and mitigate trade-offs*" (p. 18). Governance and institutional challenges faced in the implementation of the 2030 Agenda (Allen et al., 2018; UN-DESA, 2016, 2018a, 2018b) as well as insufficient coordination and communication among ministries dealing with sustainable development and fragmentation of responsibilities for SDGs implementation (UN-DESA, 2016) affect the alignment of the national

policy framework to the SDGs. Moreover, it can be argued that where the ministries of finances (or economy) have a leading role in the implementation of the SDGs (UN-DESA, 2016), there is more attention to them in budget allocation.

CONCLUSIONS

Mediterranean countries have taken concrete steps to mainstream the 2030 Agenda into their legal and policy frameworks. While in most cases the policy and planning frameworks have resulted flexible enough to accommodate the SGDs, the breadth of the 2030 Agenda and the transformative change that it calls for might require a paradigm change in the alignment of the national development policy with the Agenda. Governance challenges, such as insufficient coordination among ministries and fragmentation of mandates for SDGs implementation, affect the speed and effectiveness of the integration of the SDGs into national policy and planning frameworks. Moreover, different approaches have been used to tap into the synergies and co-benefits of some policy actions. Nevertheless, the analysis of the VNRs shows that little attention was dedicated to addressing trade-offs through policy integration. Therefore, sharing lessons and mutual learning could represent a value added and a valuable instrument to advance the 2030 Agenda implementation in the Mediterranean area and ensure a step forward from the formal description of legislation and initiatives in the VNRs. Indeed, SDGs integration into national planning and budgeting systems should go hand in hand with developing skills and knowledge, and building capacity of all stakeholders involved, including policy makers and planners. Identified issues of common concern, gaps and weaknesses could become the object of analysis, training and capacity building (including institutional support) with the help of regional and international organisations that operate in the Mediterranean. Regional initiatives such as the Multi-stakeholder platform on Sustainable Food Systems – promoted by FAO, CIHEAM and the Union for the Mediterranean (UfM) – can result instrumental in this respect.

REFERENCES

Allen, C., Metternicht, G., Wiedmann, T. (2018). Initial progress in implementing the Sustainable Development Goals (SDGs): a review of evidence from countries. Sustainability Science, 13(5), 1453–1467. https://doi.org/10.1007/s11625-018-0572-3

Anonymous (2016a). Egypt National Review Report. https://sustainabledevelopment.un.org/content/documents/10738egypt.pdf

Anonymous (2016b). Report on the implementation by France of the Sustainable Development Goals. https://sustainabledevelopment.un.org/content/documents/10726Report SDGs France.pdf

Anonymous (2017). Slovenia - Voluntary National Review on the Implementation of the 2030 Agenda. https://sustainabledevelopment.un.org/content/documents/16313Slovenia.pdf

Anonymous (2018a). Lebanon - Voluntary National Review (VNR) of Sustainable Development Goals (SDGs). https://sustainabledevelopment.un.org/content/documents/19624LebanonVNR2018.pdf

Anonymous (2018b). Malta – Voluntary National Review on the implementation of the 2030 Agenda. https://sustainabledevelopment.un.org/content/documents/20203Malta_VNR_Final.pdf

Anonymous (2018c). Synthesis of Main Messages 2018 - Voluntary National Reviews. https://sustainabledevelopment.un.org/content/documents/20027SynthesisofMainMessages2018_0607.pdf

Anonymous (2019a). Algérie : Rapport National Volontaire 2019 - Progression de la mise en oeuvre des ODD. https://sustainabledevelopment.un.org/content/documents/23441MAE_rapport_2019_complet.pdf

Anonymous (2019b). Implementation of the Sustainable Development Goals - Israel 2019 National Review. https://sustainabledevelopment.un.org/content/documents/23576ISRAEL_13191_SDGISRAEL.pdf

Anonymous (2019c). Turkey's 2nd VNR 2019. https://sustainabledevelopment.un.org/content/documents/23862Turkey_VNR_110719.pdf

Anonymous (2019d). Voluntary Review - Implementation of Agenda 2030 and the Sustainable Development Goals in Bosnia and Herzegovina. https://sustainabledevelopment.un.org/content/documents/23345VNR_BiH_ENG_Final.pdf

Council of Ministers - Republic of Albania (2018). Albania - Voluntary National Review on Sustainable Development Goals. https://sustainabledevelopment.un.org/content/documents/20257ALBANIA_VNR_2018_FINAL2.pdf

El Bilali, H., Cardone, G., Ottomano Palmisano, G., Bottalico, F., Capone, R. (2019). Implementation of the Sustainable Development Goals in the Mediterranean: institutional and governance arrangements. In, X International Scientific Agriculture Symposium "AGROSYM 2019"; October 03-06, 2019 – Jahorina, Bosnia and Herzegovina (pp. 1692–1699). Jahorina, Bosnia and Herzegovina: University of East Sarajevo. http://agrosym.ues.rs.ba/agrosym/agrosym_2019/BOOK_OF_PROCEEDINGS_2019_FINAL.pdf

Fukuda-Parr, S., Bruckner, M., Hegestad, T., Kuehner, M., Tavares, M. (2018). Voluntary National Review Reports – What do they report? CDP Background Paper No. 46, ST/ESA/2018/CDP/46. New York. https://sustainabledevelopment.un.org/content/documents/20549CDPbp201846.pdf

General Secretariat of the Government – Greece (2018). Voluntary National Review on the Implementation of the 2030 Agenda for Sustainable

Development. https://sustainabledevelopment.un.org/content/documents/19378Greece_VNR_Greece_2018_pdf_FINAL_140618.pdf

Gobierno de España (2018). Spain's Report for the 2018 Voluntary National Review. https://sustainabledevelopment.un.org/content/documents/203295182018_VNR_Report_Spain_EN_ddghpbrgsp.pdf

Government of the Republic of Croatia (2019). Croatia - Voluntary National Review of the UN 2030 Agenda for Sustainable Development Implementation. https://sustainabledevelopment.un.org/content/documents/23943CROATIA_UN_final.pdf

Italian Ministry for the Environment Land and Sea (2017). Voluntary National Review – Italy. https://sustainabledevelopment.un.org/content/documents/16341Italy.pdf

Ministry of Development – Turkey (2016). Report on Turkey's Initial Steps Towards the Implementation of the 2030 Agenda for Sustainable Development. Ankara. https://sustainabledevelopment.un.org/content/documents/107102030 Agenda Turkey Report.pdf

Ministry of Foreign Affairs - Cyprus (2017). Review on the Implementation of the 2030 Agenda in Cyprus. Nicosia.

Ministry of Foreign Affairs and Cooperation – Morocco (2016). Rapport du Royaume du Maroc concernant les premières mesures en matière de mise en œuvre de l'Agenda 2030 pour le Développement Durable. https://sustainabledevelopment.un.org/content/documents/10560NVR (Morocco).pdf

Ministry of Planning Monitoring and Administrative Reform - Egypt (2018). Egypt's Voluntary National Review 2018. https://sustainabledevelopment.un.org/content/documents/20269EGY_VNR_2018_final_with_Hyperlink_9720185b45d.pdf

Ministry of Sustainable Development and Tourism – Montenegro (2016). Voluntary national reviews at the HLPF 2016 – Montenegro. https://sustainabledevelopment.un.org/content/documents/10695Montenegro - HLPF Report.pdf

OECD (2018). Policy Coherence for Sustainable Development 2018: Towards Sustainable and Resilient Societies. OECD Publishing, Paris. https://dx.doi.org/10.1787/9789264301061-en

OECD (2019). Policy Coherence for Sustainable Development 2019: Empowering People and Ensuring Inclusiveness and Equality. OECD Publishing, Paris.

OECD & SDSN (2019). Long-term pathways for the implementation of the SDGs: the governance implications. Paris.

République Tunisienne (2019). Rapport National Volontaire sur la mise en œuvre des ODD en Tunisie. https://sustainabledevelopment.un.org/content/documents/23372Rapport_National_Volontaire_2019_Tunisie.pdf

Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G. (2018). SDG Index and Dashboards Report 2018. New York. http://www.sdgindex.org/assets/files/2018/01 SDGS GLOBAL EDITION WEB V9 180718.pdf

Sachs, J., Schmidt-Traub, G., Kroll, C., Lafortune, G., Fuller, G. (2019). Sustainable Development Report 2019. New York.

State of Palestine (2018). Palestinian National Voluntary Review on the Implementation of the 2030 Agenda. https://sustainabledevelopment.un.org/content/documents/20024VNR2018Palestine NEWYORK.pdf

Sustainable Development Goals Center for Africa & Sustainable Development Solutions Network (2018). Africa SDG Index and Dashboards Report 2018. Kigali and New York. http://unsdsn.org/wp-content/uploads/2018/07/AFRICA-SDGS-2018-Report-FINAL.pdf

UN-DESA (2016). Synthesis of Voluntary National Reviews 2016. New York. https://sustainabledevelopment.un.org/content/documents/127761701030E_2016_VNR_Synthesis_Report_ver3.pdf

UN-DESA (2018a). Synthesis of Voluntary National Reviews 2017. New York. https://sustainabledevelopment.un.org/content/documents/17109Synthesis_Report_VNRs_2017.pdf

UN-DESA (2018b). Synthesis of Voluntary National Reviews 2018. New York. https://sustainabledevelopment.un.org/content/documents/210732018_VNRs_Synthesis_compilation_11118_FS_BB_Format_FINAL_cover.pdf

UN-DESA (2019). Synthesis of Voluntary National Reviews 2019. New York. https://sustainabledevelopment.un.org/content/documents/252302019_VNR_Synthesis_Report_DESA.pdf

UN-DESA (2020). Voluntary National Reviews Database. Retrieved March 24, 2019, from https://sustainabledevelopment.un.org/vnrs

UNDG (2016). MAPS – A Common Approach to the UNDG's policy support to the SDGs - An update on implementation. March 2016. New York. https://www.un.org/ecosoc/sites/www.un.org.ecosoc/files/files/en/qcpr/doco-summary-brief-on-maps-march2016.pdf

UNEP/MAP (2005). Mediterranean Strategy for Sustainable Development: A Framework for Environmental Sustainability and Shared Prosperity. Tenth Meeting of the Mediterranean Commission on Sustainable Development (MCSD). Athens. http://mio-ecsde.org/epeaek09/basic_docs/unep_mssd_eng.pdf

UNEP/MAP (2016). Mediterranean Strategy for Sustainable Development 2016-2025. Valbonne. https://planbleu.org/sites/default/files/publications/mssd_2016-2025_final.pdf

United Nations (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015. New York. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

Original Scientific paper
10.7251/AGRENG2002029S
UDC 663.951:54(520)

MONITORING THE GROWTH AND QUALITY OF JAPANESE GREEN TEA BY UAV IMAGERY

Ayako SEKIYAMA[1]*, Kiyohisa SATO[2], Sawahiko SHIMADA[1], Tomonori FUJIKAWA[3]

[1]Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
[2]Nileworks Inc., Tokyo, Japan
[3]Faculty of Regional Regeneration Science, Tokyo University of Agriculture, Tokyo, Japan
*Corresponding author: a3sekiya@nodai.ac.jp

ABSTRACT

The optimal harvest season of Japanese green tea in Japan is judged by individual farmers based on their experiences. To confirm that optimal season, it requires a lot of efforts such as sampling of tea flushes by plucking, chemical component measuring by near-infrared spectroscopic analysis. Thus, an efficient method to determine the optimal season which can cover a wide area at once is considered highly helpful for farmers. This research measured normalized difference vegetation index (NDVI) of tea flushes by a multi-spectrum sensor mounted on an unmanned aerial vehicle. At the same time, chemical component of tea flushes was measured to compare with the result of NDVI. The result showed that the value of NDVI for the optimal harvest season of tea-leaf is 0.6 to 0.7. The result of chemical component measuring showed the increase of total free amino acids and reduction of total free sugars while tea-leaf ripens. Therefore, there was a positive relation between the value of NDVI, and total free amino acids and total free sugars. It indicates a high possibility to predict the optimal harvest season of tea flushes by NDVI.

Keywords: *Chemical components, NDVI, Remote sensing, Structure from Motion, Tea leaves.*

INTRODUCTION

The amount of exports of Japanese tea increased approximately five times in the last ten years because of global health trends and the popularity of Japanese foods in the recent years. Japanese green tea has brand power and the amount of its exports is expected to keep increasing. However, the output of green tea in Japan has been gradually decreasing last ten years due to aging and decrease of the farming population (MAFF). In Shizuoka prefecture where is located in the middle part of Japan with a temperate climate, the production of green tea is very active and occupies about 40 % (32,200 tons in dried tea leaves in 2013) of the total share in Japan (Shizuoka prefecture, 2015). The harvest season of green tea in Japan, occurs two times of late April to early May for the first picking and middle June for the second picking which is grown after the first one was picked. The first picked is

grown in March to April when it is cold. The leaves try to store lots nutrition in themselves thus the grade and selling price are higher than the second one. Since the sprout of the leaves is hardened while growing and blooming, the latter the harvest timing is, the more the output gets but the lower the quality gets. Therefore, it is very important to consider the optimal balance between quality and output because of the trade-off relation between them. Currently, the decision of the harvest timing is dependent on farmers' experience and visual observation. As an objective way, there is a method called "quadrate plucking" which plucks a certain amount of buds by hands within unit area, to measure its growth condition and quality. This enables to measure chemical component of the tea leaves and the weights of the buds to confirm the optimal harvest timing. However, most of the tea plantation is located in slope area, and it requires a hard word to conduct visual observation or quadrate plucking. For these reasons, it is expected that application of remote sensing can contribute to lowering the burden of farmers to find out the optimal harvest timing by observing in a wide area at once without direct site observation or sampling and analyzing in multiple time series.

Kim et al. (2010) found a positive correlation between Normalized Difference Vegetation Index (NDVI), and the weights of buds and fiber level, and a negative correlation between the entire quantity of nitrogen and amino acids by analyzing images obtained from a near infrared camera to monitor green tea leaves. Ishikawa et al. (2012) took the same measure and proposed establishing the quality estimate index based on green and red wavelength regions to estimate a proper harvest timing. Recently, the number of research which apply Unmanned Aerial Vehicle (UAV) has been increasing because of its high portability and the increasing popularity due to the lowering price. UAV enables us to create images with higher resolution and obtain images more frequently compared to satellite images. Thus, it is useful to observe the growing crops frequently. The use of UAV in the agricultural field is growing. For example, Hama et al. (2018) applied UAV to take images of rice from the period of the emergence of ears till the period of maturity, to estimate the amount of harvest. Sato et al. (2016) investigated the effective wavelength region to measure the growth level of tea leaves by filtering the camera equipped with UAV. However, the quantitative method to clarify the optimal harvest timing for the first picking has not been established. Therefore, this research attempts to propose a monitoring method for the tea leaves by applying aerial images taken by a multi-spectrum camera equipped with UAV. Concretely, it discusses the possibility to estimate the growing condition and quality of the first picking by analyzing the relation between chemical components of the tea flushes taken by the quadrate plucking and spectral characteristics of the tea flushes.

MATERIALS AND METHODS

The project site is a tea filed in Kikugawa City, Shizuoka Prefecture where located in the middle part of Japan (Fig. 1a). The targeted breed is Yabukita (*Camellia sinensisis (L.) O Kuntze cv. 'Yabukita'*), grown in a moderate slope area. The onsite

investigation took four days (29 April, 1, 3 and 10 May 2017) in total during the growing period of the first picking.

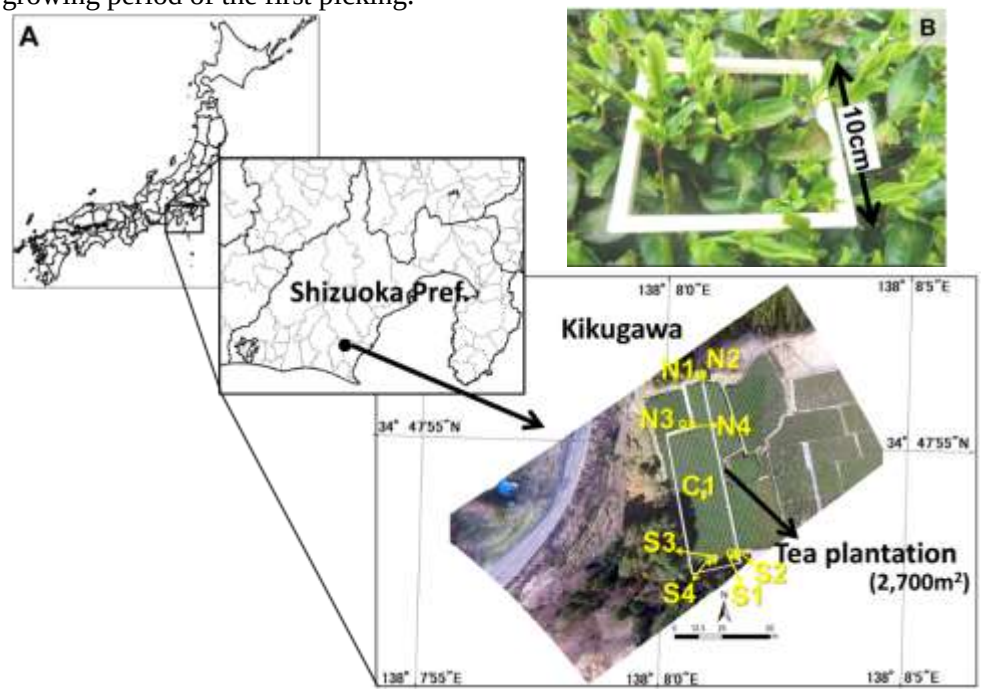

Figure.1 Location of tea plantation field and sampling points of tea leaves (a). Frame of quadrate plucking for tea leaves (b).

Aerial images were taken by UAV and quadrate sampling was conducted in nine points (four points in northern part, four points in Southern part, and one point in the middle part of the field) for analysis of the chemical components. Thus, the total was thirty-six samples. In analysis of the chemical components, the buds within a wooden frame of ten centimeters square were plucked, frozen by liquid nitrogen and then analyzed by a gas chromatography-mass spectrometer (QP2010 Plus by Shimadzu Corporation). Through this analysis, totally twenty chemical components such as aspartic acid, theanine and caffeine were measured (Table 1).

Table 1. Measured chemical components

Pyruvic acid	Serine	Glutamic acid	Galacturonic acid
Alanine	Threonine	Glutamine	Inositol
Oxalic acid	Malic acid	Fructose	Sucrose
Succinic acid	Aspartic acid	Citric acid	Caffeine
Glycine	GABA	Glucose	Theanine

To make aerial images taken by UAV ortho-rectified photo mosaic or orthomosaic, the latitude, longitude and altitude of ground control point (GCP) which was set up in the target field based on the measure by RTK-GNSS, were measured.

For aerial photograph, a UAV, Inspire 1 by SZ DJI Technology Co., Ltd. and a multispectral sensor, Sequoia by Parrot Drones SAS, were applied. Sequoia can obtain spectral data of four separate bands (Green: 530 to 570 nm, Red: 640 to 680 nm, Red Edge: 725 to 745 nm, Near infrared: 770 to 810 nm). The flight altitude was set at 30 m and images were captured by automatic pilot using a free drone flight application, Pix4Dcapture by Pix4D S.A. The taken images were processed orthomosaic by a Structure from Motion (SfM) software, Pix4Dmapper. The pixel resolution of all the images was 3 cm. NDVI images were created from each orthomosaic images.

The value of NDVI responding to each sample of tea flushes were identified after calculating the average value in each pixel of NDVI images which corresponds to the sampled points. Since the resolution of pixel is 3 cm, about nine pixels are measured which cover the 10 cm square sampled by quadrate plucking.

RESULTS AND DISCUSSION

Images taken in each investigation day are shown in Fig. 2. In all these dates, the NDVI values are higher in the southern part of the field than the northern part. It is considered the long sunlight length compared with the northern part. The NDVI value in the entire field increased throughout the period from 29 April to 10 May.

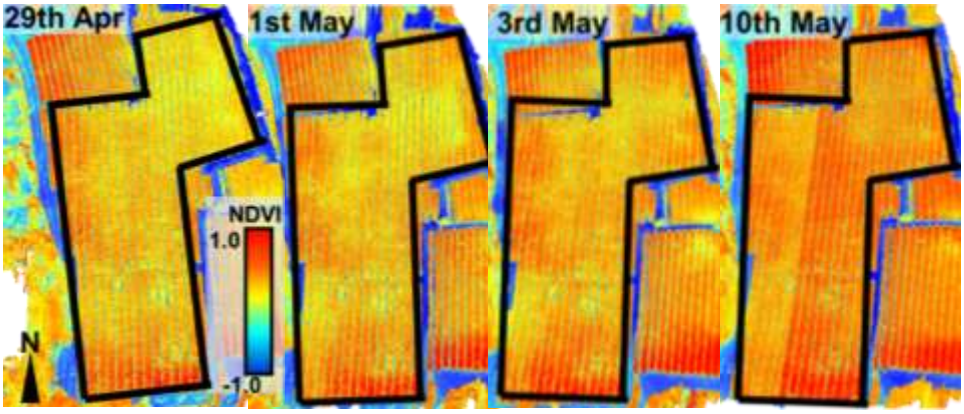

Figure.2 Change of NDVI distribution at tea plantation field

The NDVI values that correspond to each sampling point by quadrate plucking for each investigation day are shown in Fig. 3. The N3, N4, S3 and S4 are not included in this analysis because these were cultivated before 10 May. Every sampling point showed the increased of NDVI values throughout the survey period. In addition, the NDVI values are lower in the northern part than the southern part throughout the time. On the first day, the difference of the NDVI value is twice as much between the northern and southern parts. However that difference became smaller

by 10 May, a day before the harvest and the number of error in standard deviation also decreased. Therefore, it is assumed that the maturity within the field is uniformized as the harvest period comes close. The lowest NDVI value was 0.6 at the sample point, C1, the highest were 0.67 in S1 and S2 on 10 May. Thus, it is expected that the NDVI value for the harvest for the first picking is approximately between 0.6 and 0.7. From these reasons, it shows that when NDVI values reach around these values, it is the time for harvest of the tea flushes.

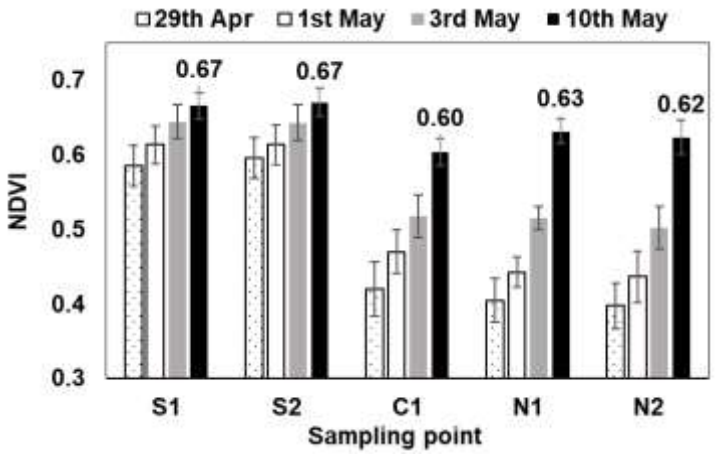

Figure. 3 Change of NDVI each sampling point (Bars represent Standard Deviation)

On the other hand, principal component analysis (PCA) was conducted to investigate how the chemical components change over the investigation time and whether its change depends on a kind of chemical component (Fig. 4). Especially, this research focused on changes in total free amino acid such as theanine, glutamic acid, aspartic acid and serine, and total free sugar such as sucrose, glucose and fructose. Thus, it is considered that the result of PCA shows that the first principal component is the factor for total free amino acid and the second principal component is for total free sugar. Furthermore, the score of both total free amino acid and total free sugar showed the inverse relationship for each principal component, and there is a trade-off relationship such as that as total free amino acid increases, total free sugar decreases. From these results, it is presumed that the amount of amino acids and sugar changes as the tea leaves matures. In addition, scatter diagrams were created for each investigation day based on the principal component scores obtained from the result of PCA (see Fig. 5). Although there was not much difference in chemical components between 29 April and 3 May, the second principal component which is total free sugar, significantly increased by 10 May, the day before harvesting. As it is known that the sweetness of green tea is contributed by sugar, it is presumed that its sweetness increases as the tea leaves matures. It is also known that as the growth of the tea leaves accelerates, the consumption amount of amino acid for the growth of buds lowers than the amount

of translation from the roots to buds (Hakamada and Maehara, 1978). The results of this research can validate it. Single regression analysis was conducted for the NDVI images created based on all the chemical components and aerial images taken by UAV. The result showed the strong negative correlation (R=0.72**, P < 0.001) between aspartic acid and the NDVI value. Considering that the ideal NDVI value for the harvest time is between 0.6 and 0.7, the ideal aspartic acid amount for harvest time is between 0.5 to 1.5μmol/100g. There was no any other chemical component which showed a strong correlation with several vegetation indices including NDVI. As seen from the result of PCA, there is a difficulty of approximation by regression equation since the chemical components contained in the tea leaves do not change gradually in accordance with its growth but suddenly changes immediately before the time of harvest.

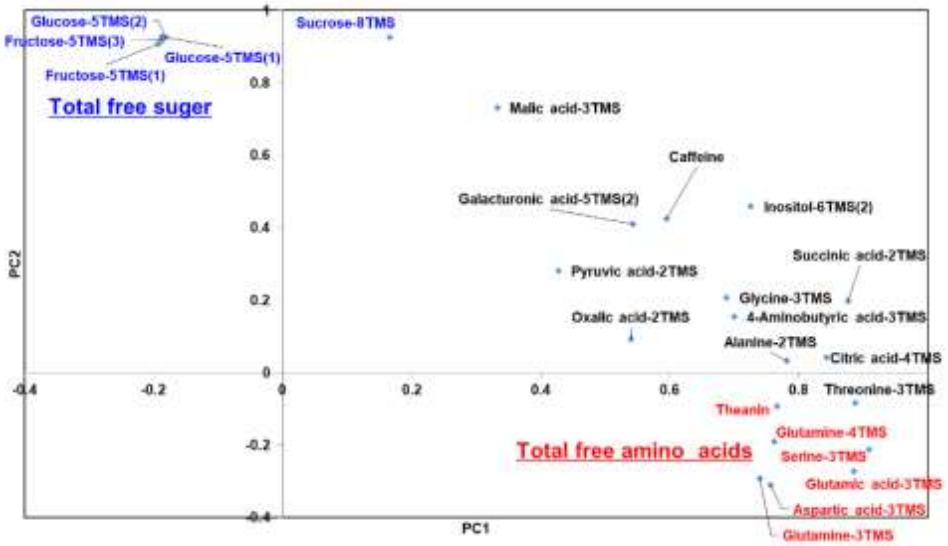

Figure. 4 Principle component analysis using chemical components at tea plantation

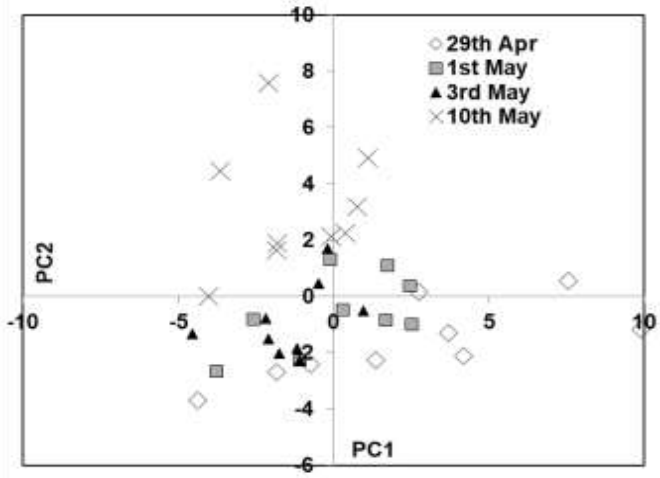

Figure. 5 Distribution of principle component score each day

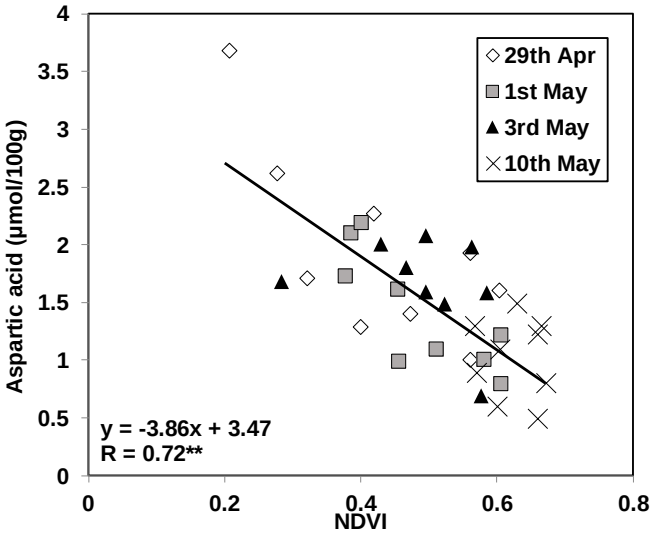

Figure. 6 Relationship between NDVI and Aspartic acid

CONCLUSION

This research discussed if it is possible to determine the optimal harvest time for the first picking of green-tea leaves by using UAV images rather than depending on experiences by farmers. In addition, the UAV images and the samples of the tea leaves were taken at the same time and the relation of vegetation index gained from the UAV images and chemical components gained from the sampling was analyzed. As the results, the following findings were shown:

- The NDVI value all over the tea plantation field at the time immediately before harvesting was between 0.6 and 0.7. It assumed that around these

values imply the optimal harvest time for the first picking.

- The relation between total free amino acids and sugar is tradeoff as the tea leaves grow, based on the investigation into changes of chemical components of the tea leaves.
- There is a correlation between the NDVI values and aspartic acid. There is possibility to predict the amount of aspartic acid based on the NDVI values.

REFERENCES

Shizuoka Prefecture, Japan. (2015). White paper of Japanese green tea.

Jong-Hwan KIM, Byungdug JUN, Kazuichi SUGIYAMA, Kenji TORAO, Yoshihiko, HORIUCHI, Hitoshi IRYOU and Masahiko ARAI. (2010). A Method of Yield and Quality Estimation for Tea-plant Using On-site Remote Sensing. *Journal of the Japanese Agricultural Systems Society*. **26(1)**, pp.1-8.

Daitaro ISHIKAWA, Ayaka NSHIWAKI, Takuto NISHIMOTO, Naoya CHlSHAKI, and Etsuji ISHIGURO. (2011). Study on Nondestructive Estimation Method for Growth and Quality in Tea Leaves Using Proximal Remote Sensing Method -Development of Estimation Method of Optimum Harvesting Period for Fresh Leaves using Spectral Image and Application to Fertilization. *Journal of the Japanese Society of Agricultural Technology Management*. **18(3)**: pp.115-122.

Akira HAMA, Kei TANAKA, Atsushi MOCHIZUKI, Hiroyuki ARAI, Toshiyuki HIRATA, Ryuya YAWATA, Yasuo TSURUOKA and Akihiko KONDOH (2018). Estimating Paddy Rice Plant Height and Yield Using UAV Remote Sensing and Solar Radiation. *J. Japan Soc. Hydrol. and Water Resour.* **31(2)**: pp.68-82.

Satoh KIYOHISA, Sawahiko SHIMADA, Ayako SEKIYAMA, Hiromichi TOYODA, Tamon YANAI and Nobuhiro HORI (2016). Extraction of Near-infrared Information from Aerial Photography Using UAV with Supergel Color Filter Aiming for In-situ Tea growing Monitoring. *Journal of The Remote Sensing Society of Japan*,**36(2)**, pp.131-135.

Katsuhiro HAKAMATA and Mitoshi MAEHARA (1978). Changes in Total Nitrogen, Free-Amino Acids, Caffein and Tannin of Tea Leaves with Special Reference to the development of New Shoots. *Tea Research Journal*. **48**. pp.57-63.

MAFF: Ministry of Agriculture, Forestry and Fisheries, Japan (2009-2018). Census of agriculture and forestry.URL:https://www.maff.go.jp/j/tokei/kouhyou/sakumotu/sakkyou_kome/index.html#r. Accessed 09.01.2020.

Original Scientific paper
10.7251/AGRENG2002037A
UDC 634.11:631.53

CLONAL PROPAGATION CAPACITY OF TWO NEW APPLE ROOTSTOCKS BY STOOLING

Ola T. ALHALABI*, Bayan M. MUZHER

General Commission for Scientific Agricultural Research, Syria
*Corresponding author: ola_halabi@msn.com

ABSTRACT

This investigation was carried out at General Commission for Scientific Agriculture Research – Pome and Grapevine Division in Sweida governorate (Syria), from 2013 to 2017, to evaluate the ability of two new local apple rootstocks (SukariAlswieda 'S'and SkarjiAlswieda 'H') to vegetative propagation in stool bed. The results showed that the second year of propagation significantly produced the highest number of rooted shoots (liners) from each rootstock (7 liners and 5 liners in 'S' and 'H' respectively). 'S' and 'H' rootstocks revealed significant difference in average produced liners. However, the length and diameter of liners from 'H' rootstock did not show significant difference among studied years, they were in average 59.1 cm and 6.1 mm respectively.While as, the highest length and diameter of liners from 'S' were in the third year (82.3 cm and 7.6 mm respectively). On the other hand, the two studied rootstocks produced liners with good and stable root system which differed in structure between them, that 'S' rootstock revealed coarse (woody) roots, while in 'H' rootstock the roots were hairy. The number of roots was in average 17 roots and 12 roots in the liners of 'S' and 'H' respectively.As well as. the average length of liners roots were 23.4 cm and 22.2 cm in 'S' and 'H' respectively. Consequently, the clonal propagation for the studied rootstocks in stool bed is a sufficient tool to produce liners similar to the plant parent and they are ready to be budded with cultivars scions.

Key words: *apple, rootstock, vegetative propagation, stool bed.*

INTRODUCTION

Apple rootstocks were used as an easy way of propagating scion cultivars. Nowadays, rootstocks play an important key factor in tree growth and physiology, therefore they have to provide many other valuable characteristics to the orchard tree, such as control growth vigor of trees, induce precocious, help consistent and abundant yields, and tolerance/resistance to pests, diseases and abiotic stress factors (Rober, 2001; Webster, 2003; Dolgov and Hanke, 2006).

Apple growers depend on seedling rootstocks, only in the countries which are difficult to use vegetative rootstocks, or they are not economical (Webster and Wertheim, 2003). However, seedling rootstocks have many advantages rather than

vegetative rootstocks, that they are easy and cheap in propagation, virus free, and free from soil rots (Wertheim and Webster, 2003). Seedling rootstocks produce huge tree between 7 and 10 m in height and spread, while lower size of tree is preferable in most of apple production regions in the world, all of these lead to use vegetative rootstocks which provide wide range of vigor growth, from very dwarf rootstock such as M27, to vigorous rootstock as M25 (Webster and Wertheim, 2003). Moreover, vegetative rootstocks have many compensations over seedling rootstocks, like the ability to control tree size, increase productive efficiency, achieve uniformity and precocity (Wertheim and Webster, 2003).

Vegetative propagation of clonal apple rootstocks is mostly made by division techniques either stooling or layering (Webster, 1995); however, division techniques are ancient applications which were described by Knight *et al*. (1928). Beside division techniques, cutting techniques were used for clonal apple rootstocks propagation (Roberts and Mellenthin, 1957;Hartmann *et al.*, 1965;Rahimi Dvin *et al.*, 2011). Comparatively little numbers of clonal apple rootstocks are propagated by cutting techniques, as well as micro-propagation and root cuttings (Webster, 1995). In Syria apple is an important tree. There are more than 100 cultivars in the GCSAR germplasms (Muzher and Al Halabi, 2012). In addition, there are new selected clonal rootstocks from apple rootstock breeding program such 'S' and 'H' (Al Halabi *et al*., 2012). Therefore, this investigation aimed to study the ability of two new local apple rootstocks to vegetative propagation in stool bed.

MATERIALS AND METHODS

This investigation was achieved during 2013-2017 at Pome and Grapevine Division- GCSAR in Sweida governorate which located in the south of Syria at 1525 m altitude.

Plant material

Two new Apple rootstocks: Sukari Alswieda 'S' is produced from local apple cultivar, and Skarji Alswieda 'H' is a hybrid between MM106 rootstock and the local apple cultivar Skarji.

Methods

Stooling

One-year old rooted plants (9 for each rootstock) were planted vertically in 2013 spring, and left un pruned for 1 year. In 2014 spring the stems were cut back to 2-3 cm. The distance between rows was 1 m, and within the rows was 30 cm. Earthing up of the young shoots was achieved according to Wertheim and Webster (2003). After natural leaf drop, the ridge of soil was forked away and the rooted shoots (liners) were cut loose from parent plants. This process was repeated annually for three years.

Studied parameters

After liners were cut loose the following parameters were studied per parent plant:

- Number of rooted shoots (liners).
- Mean length of liners
- Mean diameter of liner's stem at 15 to 20 cm height.
- Root system of liner:
    - Structure of liner's root (hairy or coarse).
    - Mean number of root.
    - Mean Length of roots.
    - Mean diameter of roots.

Experimental design and statistical analysis

The experiment was designed in completely randomized design (CRD), data were analyzed using analysis of variance (ANOVA) to compare liners means for measured parameters, mean comparison was achieved using LSD test ($p < 0.05$).

RESULTS AND DISCUSSION

Number of rooted shoots (liners) per parent plant

The result showed that the highest number of liners was in the second year (7 liners and 5 liners in 'S' and 'H' rootstocks respectively), the difference was significant with first and third years in 'S' rootstock, while it was significant with the third year only in 'H' rootstock (Figure 1). On the other hand, 'S' rootstock significantly produced liners in stool bed more than 'H' rootstock in the studied years, they were in average 5 liners per 'S' rootstock, and 3 liners per 'H' rootstock. These results reflected the variance ability of propagation in studied rootstocks using stool bed. This was in agreement with Wertheim and Webster (2003), that clonal rootstocks vary in the number of rooted shoots, however the results of stooling propagation at East Malling Research Station ranged between 2.6 per stool for M9 to 13.4 for MM104 (Howard, 1977).

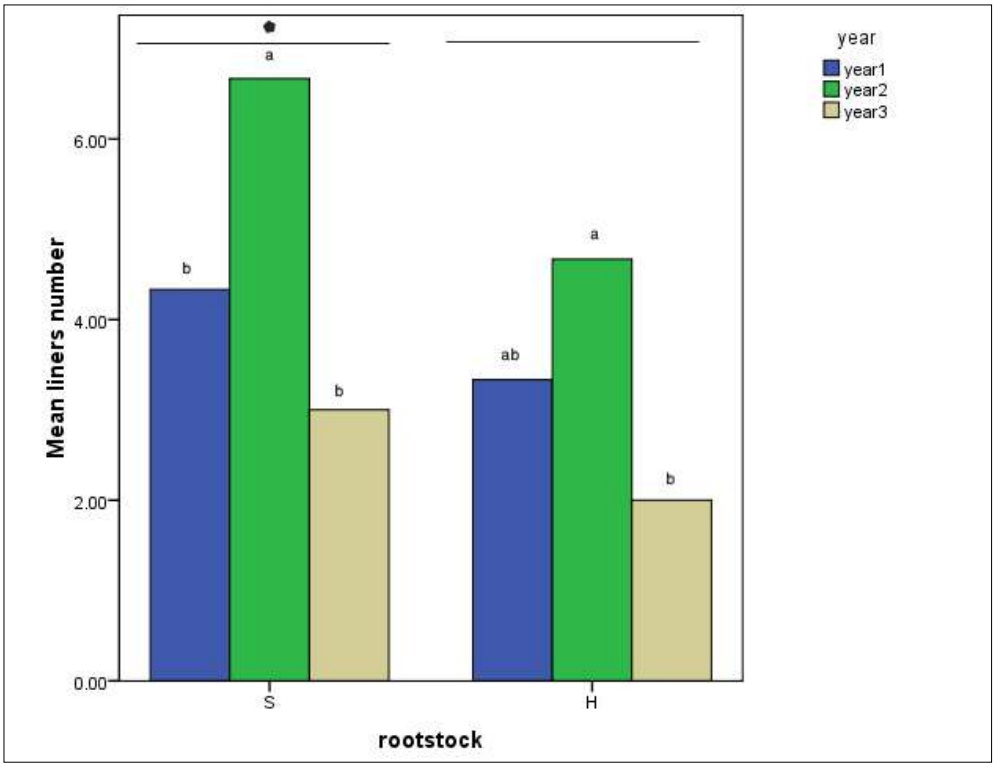

Figure (1): Mean liners number of 'S' and 'H' in stoolbed during studied years. ($LSD_{5\%}$ between years = 1.88 and 2.5 for 'S' and 'H' respectively, $LSD_{5\%}$ between rootstocks = 0.85)

Similar letters (a,b,) in each bar of each rootstock indicated that the variance is insignificant.

*indicated that the variance is significant between rootstocks.

Mean length and diameter of liners per parent plant

The mean length and diameter of liners which were produced from 'S' rootstock significantly differed among studied years. The highest length and diameter were in average 82.5 cm and 7.6 mm respectively in the third year (Table 1). This due to the low number of liners were produced from each parent plant. While 'H' did not reveal significant differences in plant length and diameter among studied years (Table 1). This result reflected the stability of 'H' liners traits in stool bed. However, the difference between the studied rootstocks was insignificant in plant length, while 'S' significantly showed higher plant diameter than 'H'. Moreover, the results in table (1) showed that the diameter of liners especially from 'S' were suitable for budding with scion cultivars according to Wertheim and Webster (2003).

Table 1. Mean length and diameter of liners produced from 'S' and 'H' rootstocks in stoolbed.

	Mean length (cm)			**Mean diameter (mm)**		
Rootstock	**'S'**	**'H'**	**Mean**	**'S'**	**'H'**	**Mean**
First year	64 b	57.2	60.6 ab	7.2 ab	6	6.6 ab
Second year	50.3 c	46	48.1 b	6.8 b	5.8	6.3 b
Third year	82.3 a	74.1	78.2 a	7.6 a	6.6	7.1 a
Mean	**65.5**	**59.1**	**62.3**	**7.2***	**6.1**	**6.7**
LSD5% (years)	9.6	-	19.6	0.52	-	0.8
LSD5% (rootstocks)	-			0.8		

Similar letters (a,b,c) in each column indicated that the variance is insignificant.
*indicated that the variance is significant between rootstocks.

Root system of liners per parent plant

The results showed that the two studied rootstocks differed in the structure of root system of liners. However, 'S' rootstock revealed separated and coarse (woody) roots similar to the obtained roots by seed propagation, this considered as a plus feature to this rootstock. While in 'H' rootstock the roots were hairy gathered into groups (Figure 2).

The results in Table (2) illustrated that the average number of roots per liner was 17 roots and 12 roots in 'S' and 'H' respectively. The average of root length and diameter were 23.4 cm and 2.6 mm in the liners of 'S' rootstock, and 22.2 cm and 2.2 mm in the liners of 'H' rootstock. These results were insignificantly differed between the two rootstocks and among years of study, except the average number of roots in the third year, which was superior above second year. Consequently, the two rootstocks gave plants with good and stable root system, which is necessary in rootstock production. However, this issue is the most important concept of apple rootstock breeding programs worldwide (Cummins and Aldwinckle, 1995; Janick *et al.*, 1996; Webster *et al*., 1997; Bite and Lepsis, 2007; Johanson *et al*., 2007).

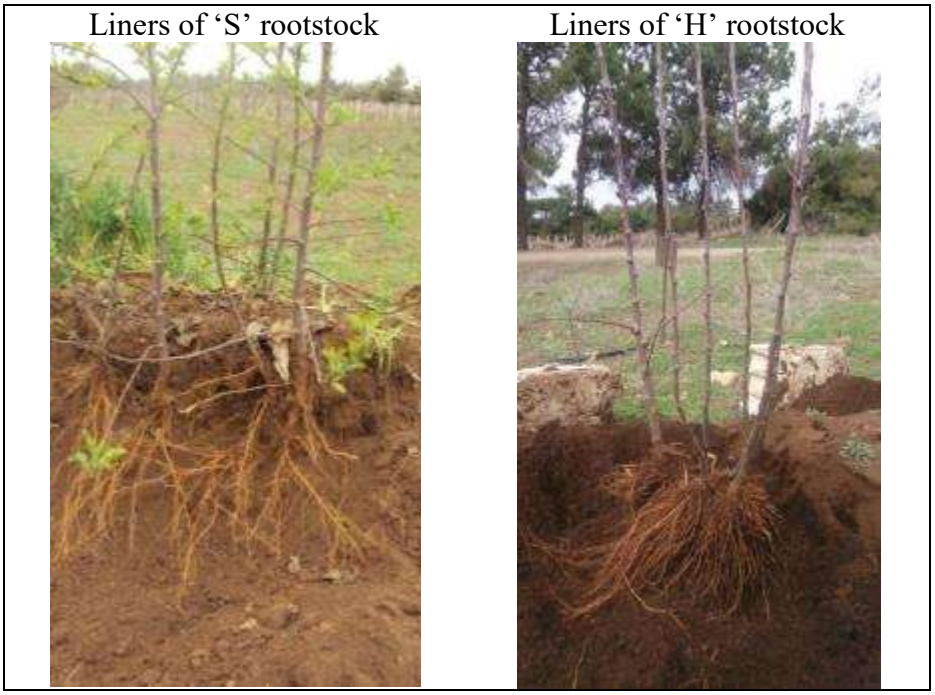

Figure 2. root system of liners produced by stooling from 'S' and 'H' rootstocks.

Table 2.Mean roots number, Mean root length and diameter of liners produced from 'S' and 'H' rootstocks in stoolbed.

	Mean roots number (root)			**Mean root length (cm)**			**Mean root diameter (mm)**		
Rootstock	**'S'**	**'H'**	**Mean**	**'S'**	**'H'**	**Mean**	**'S'**	**'H'**	**Mean**
First year	20	12	16 ab	26.5	24	25.2	3	2.6	2.8
Second year	12	7	10 b	20.5	22.6	21.6	2.4	2.2	2.3
Third year	17	17	17 a	23.3	20	21.7	2.6	1.7	2.2
Mean	17	12	14	23.4	22.2	22.8	2.6	2.2	2.4
LSD5% (years)	-	-	**6.5**	-	-	-	-	-	-

Similar letters (a,b) in each column indicated that the variance is insignificant.

CONCLUSION

Stool bedpropagation of the studied rootstocks showed that the two rootstocks gave different numbers of liners, with good traits of stem length and diameter, beside root system (number of roots, root length and diameter). Thus, stooling is a sufficient tool to produce liners similar to the plant parent and they are ready to be budded with cultivars scions.

REFERENCES

Al-Halabi, O., T., Muzher, B., M. and Hamed, F. (2012). Preliminary evaluation of some apple seedlings rootstocks genotypes in apple rootstock breeding program. Damascus University Journal for the Agricultural Sciences, 28(2): 473-483.

Bite, A. and Lepsis, J. (2007). Preliminary Evaluation of New Apple Clonal Rootstocks in Latvia. Acta Hort., 732:177-179.

Cummins, J. N. and Aldwinckle, H. S. (1995). Breeding rootstocks for tree fruit crops. New Zealand Journal of Crop and Horticultural Science, 23: 395-402.

Dolgov, S. V. and Hanke, M. V. (2006). Transgenic temperate fruit tree rootstock. In: Tree transgenesis recent developments, Fladung, M. and Ewald, E. (Eds.). Springer, Hiedelperg. pp:335-350.

Hartmann, H. T., Hansen, C. J. and Loreti, F. (1965). Propagation of apple rootstocks by hardwoodi cuttings. C a l i f o r n i a Agriculture, pp. 5.

Howard, B. H. (1977). Effects of initial establishment practice on the subsequent productivity of apple stoolbeds. Journal of Horticultural Science, 52: 437-446.

Janick, J., Cummins, J. N., Brown, S. K. and Hemmat, M. (1996). Apples. In: Janick, J. and Moore, J. N. (Eds). Fruit Breed, volume I: Tree and Tropical fruits. Pp: 1-77.

Knight, R. C., Amos, J., Hatton, R. G. and Witt, A. W. (1928). The vegetative propagation of fruit- tree rootstocks. In: Annual report East Malling Research Station for 1926, Vol. II, Supplement. Maidstone, UK, pp. 11-30.

Muzher, B. and Al-Halabi, O. (2012). Evaluation of the most important apple varieties in Syria. Damascus university journal for agriculture science, 28(1): 65-76.

Rahimi Dvin, S., Ganji Moghadam, E. and Kiani, M. (2011). Rooting response of hardwood cuttings of MM111 apple clonal rootstock to Indolebutyric acid and rooting media. Asian Journal of Applied Science, 4(4): 453-458.

Roberts, A. N. and Mellenthin, W. M. (1957). Propagating clonal rootstock. Agricultural Experiment Station Oregon State College Corvallis, pp:7.

Webster, A. D. (1995). Temperate fruit tree rootstock propagation. New Zealand Journal of Crop and Horticultural Science, 23: 355-372.

Webster, A. D**.** (2003). Breeding and selection of apple and pear rootstocks. Acta Hort., 622: 499- 512.

Webster, A. D., Tobutt, K. .R., James, D. J., Evans, K. M. and Alston, F. A.(1997). Rootstock Breeding and Orchard Testing at Horticulture Research International - East Malling. Acta Hort., 451:83-88.

Webster, A.D. and Wertheim, S.J. (2003). Apple rootstocks, In: Botany, Production and Uses, D.C. Ferree and I.J. Warrington (eds.), *CAB* International. pp. 91-124.

Wertheim, S.J. and Webster, A. D. (2003). Propagation and Nursery Tree Quality, In: Botany, Production and Uses, D.C. Ferree and I.J. Warrington (eds.), *CAB* International. pp. 125-151.

Professional paper
10.7251/AGRENG2002044K
UDC 004:638.1

AUTOMATED SYSTEM FOR BEE COLONY WEIGHT MONITORING

Armands KVIESIS[1], Aleksejs ZACEPINS[1*], Sascha FIEDLER[2], Vitalijs KOMASILOVS[1], Janis LACEKLIS-BERTMANIS[3]

[1]Department of Computer Systems, Faculty of Information Technologies, Latvia University of Life Sciences and Technologies, Jelgava, Latvia
[2]Department of Agricultural and Biosystems Engineering, University of Kassel, Kassel, Germany
[3]Faculty of Engineering, Latvia University of Life Sciences and Technologies, Jelgava, Latvia
*Corresponding author: aleksejs.zacepins@llu.lv

ABSTRACT

Real time, continuous and remote monitoring of the honeybee colonies with application of information and communication technologies (ICT) is becoming increasingly frequent in industry and in a scientific research. Combination of ICT and beekeeping led to the development of the Precision Beekeeping approach. Successful implementation of the Precision Beekeeping system includes development of the bee colony monitoring hardware solution and computer software for data collection and further analysis. This paper describes developed and implemented bee colony monitoring unit for weight and temperature monitoring. Bee colony weight is one of the key metrics of the strength of a colony. Changes in weight can reflect the productivity rate of the colony, as well as its health and state. Developed monitoring system is based on Raspberry Pi Zero W single board computer with several connected sensors for bee colony temperature and environmental parameter monitoring. Weight is measured using single point load cell with possibility to measure weight up to 200kg, which is enough for the beehive measurements. Data transfer from the remote bee colony is provided by the external 3G router. For data storage and analysis cloud-based data warehouse is developed. Collected data is accessible in the web system with user friendly interface for data visualisation and reporting. Within this research scale calibration process is described and accuracy of the weighting is evaluated and possible challenges are discussed. Described monitoring system is developed within the Horizon 2020 project SAMS, which is funded by the European Union within the H2020-ICT-39-2016-2017 call. To find out more visit the project website https://sams-project.eu/.

Keywords: *Precision Beekeeping, Precision Apiculture, weight monitoring, bee colony monitoring, SAMS project*.

INTRODUCTION

Insects are the main pollinators for agricultural and horticultural plants (Kremen, Williams, & Thorp, 2002; Partap, 2011). Up to 79% of the human food supply today is dependent on pollination, and the honey bee is the most widespread and active pollinator animal worldwide (Bradbear, 2009; Breeze, Bailey, Balcombe, & Potts, 2011). Besides the important aspect of pollination, honey bees also produce a variety of valuable bee products like honey, beeswax, pollen and etc. which also leads to an economic benefit for the beekeeper (Crane, 1990). Recently Precision Beekeeping (Precision Apiculture) has been defined, as apiary management strategy based on individual bee colony monitoring (Aleksejs Zacepins, Brusbardis, Meitalovs, & Stalidzans, 2015). Within the Precision Beekeeping hardware and software solutions should be developed and implemented to assist the beekeeper by providing real-time data and decisions about the bee colonies and their states. The monitoring of honeybee colonies over long periods of time can result in long-term data for better analysis and understanding of the colony behaviour (Lecocq, Kryger, Vejsnæs, & Jensen, 2015; Odoux et al., 2014; Simon-Delso et al., 2014).

Behaviour and state of bee colonies can be monitored by use of temperature, humidity, acoustic, video, weight and other sensors (W. G. Meikle & Holst, 2015). Continuous monitoring of those parameters is becoming feasible for most beekeepers as the cost and size of the end devices decrease while their precision and capacity increase. Additional benefit of the remote monitoring of colonies is in minimising the number of local manual colony inspections as frequent, physical inspections of bee colonies interferes bees and can cause additional stress, that negatively affects the whole colony productivity (Komasilovs, Zacepins, Kviesis, Fiedler, & Kirchner, 2019; Zabasta, Zhiravetska, Kunicina, & Kondratjevs, 2019). As well implementation of the bee colony monitoring solutions provides economical benefit for the beekeepers, taking into account that every inspection of the remote apiary adds additional transportation costs to the beekeepers (W. G. Meikle & Holst, 2015; Zetterman, 2018).

Bee hive weight provides one of the most important kinds of data beekeeper can have about the colonies (Fitzgerald, Edwards-Murphy, Wright, Whelan, & Popovici, 2015). Automated weight systems can supply the beekeeper with important information on several important events from the honey bee colonies (Buchmann & Thoenes, 1990; McLellan, 1977; W. Meikle, Hoist, & Mercadier, 2006). Weight is related to such important activities of the bee colony like starting of nectar collection, resource consumption by the colony indicating the need of additional feeding. Weight data shows the beekeepers when to add supers or start a honey harvesting. Commercial beekeepers can use beehive scales to save unnecessary visits to the apiary when they do long-distance migration (Human & Brodschneider, 2013).

Idea of weighing of the bee colonies is not new, since the 1950s it is suggested to use weight as an indication of health and productivity (McLellan, 1977), and today there are a big number of ready commercial and homemade solutions for this

purpose available for the beekeepers (Human & Brodschneider, 2013). One major difference among different vendors and systems is the number of load cells in the product, which may be one, two, or four, but any of these arrangements will work. https://colonymonitoring.com/current-sensors/ summarised many vendors and their products in one place. Besides the commercial products many handmade systems are available too. As well some scientifically used solutions are described in many publications (Cecchi et al., 2019; Fitzgerald et al., 2015; Gil-Lebrero et al., 2016; Ochoa, Gutierrez, & Rodriguez, 2019; Sengul Dogan, Erhan Akbal, 2017; Terenzi, Cecchi, Spinsante, Orcioni, & Piazza, 2019; Zabasta et al., 2019; A. Zacepins, Pecka, Osadcuks, Kviesis, & Engel, 2017).

Additional value of the bee colony monitoring is an option to geographically distribute and install of automated electronic scales (Lecocq et al., 2015), then share the collected data with other beekeepers to inform about the start of the nectar flow in different geographical regions. There are several such initiatives found in the web (list is not full and there are many more such systems):

- http://honeybeenet.gsfc.nasa.gov – the NASA Goddard Space Flight Centre has initiated a project in which the daily weighing of hives by volunteer beekeepers are merged with satellite data (Nightingale, Esaias, Wolfe, Nickeson, & Ma, 2008).
- https://www.beeandmegmbh.com/global-map-bee-hives - some of the beehive worldwide made public by the BeeAndme for scientific, collaborative or information purposes.
- http://mybees.buzz/ – this Web system shows data about main bee colony parameter changes from different Nordic countries, including Denmark, Sweden, Norway, Latvia and Estonia. System is developed by the Danish Beekeepers Association.
- svari.strops.lv – this Web systems shows data from several bee colonies located in Latvia using the Capaz monitoring system. System is developed by the Latvian Beekeeping Association.

The aim of this paper is to describe the developed honey bee colony weight monitoring system for weight and temperature measurements using one load cell, as load cells become a standard in bee colony weighing systems and Raspberry Pi Zero (Arduino, ESP?) computer.

Development of the bee colony weigh monitoring system is done within the Horizon 2020 project SAMS. A combined biological, sociological and technical approach is made within the SAMS - Smart Apiculture Management Services - project (https://sams-project.eu/).

DEVELOPED SYSTEM FOR WEIGHT AND TEMPERATURE MONITORING

Inapplicability for outdoor conditions of continuously loaded general purpose electronic scales and sometimes the high costs of the available commercial solutions limits their application in Precision Beekeeping. Manual weighing of the

colonies is possible, but too laborious to perform frequently and also procedure of lifting the hive and putting on the scales makes addition disturbance to the bee colony (Stalidzans et al., 2017). So still there is an open possibilities and open market for development of affordable and reliable solution for the automated bee colony weighting.

Authors of this research developed prototype of honeybee colony weight monitoring system based on single point load cell (BOSCHE Wagetechnik Single point load cell H30A, https://www.bosche.eu/en/scale-components/load-cells/single-point-load-cell/single-point-load-cell-h30a) with max load of 200kg and Raspberry Pi Zero W single board computer. In addition, two sensors are added to the system for bee colony temperature and environmental humidity and temperature monitoring. For getting the weight data analogue/digital converter HX711 is used. At this stage system is powered by standard 220V power supply, but in the future, it is planned to implement power management from renewable energy sources (e.g. solar power) and additional battery for energy storage. As well for data sending to the remote server wi-fi network (provided by the 3G router) is used, but it can be easily substituted by mobile network adding additional module to the Raspberry Pi directly or even using modern data transfer technologies, like LoRaWAN (A Zacepins et al., 2018) or other. At this moment system is assembled using the breadboard, but after testing separate printed circuit board with casing will be designed and manufactured. Developed system's architecture is based on proposed approach by (Kviesis & Zacepins, 2015) where individual measurement node sends monitoring data to the remote server via wireless or mobile network.

Load cell is mounted between two metal plates (10cm x 15cm), and then metal plates are screwed to the plywood plates (50cm x 50cm) as described in the load cell manual. Beehive can be placed directly on the platform or some additional wooden planks can be used. Mounting of the load cell is shown in Figure 1.

Economic aspect is very crucial for the beekeepers, therefore system costs should be as minimal as possible. In authors case costs for system components and additional materials are summarised in Table 1.

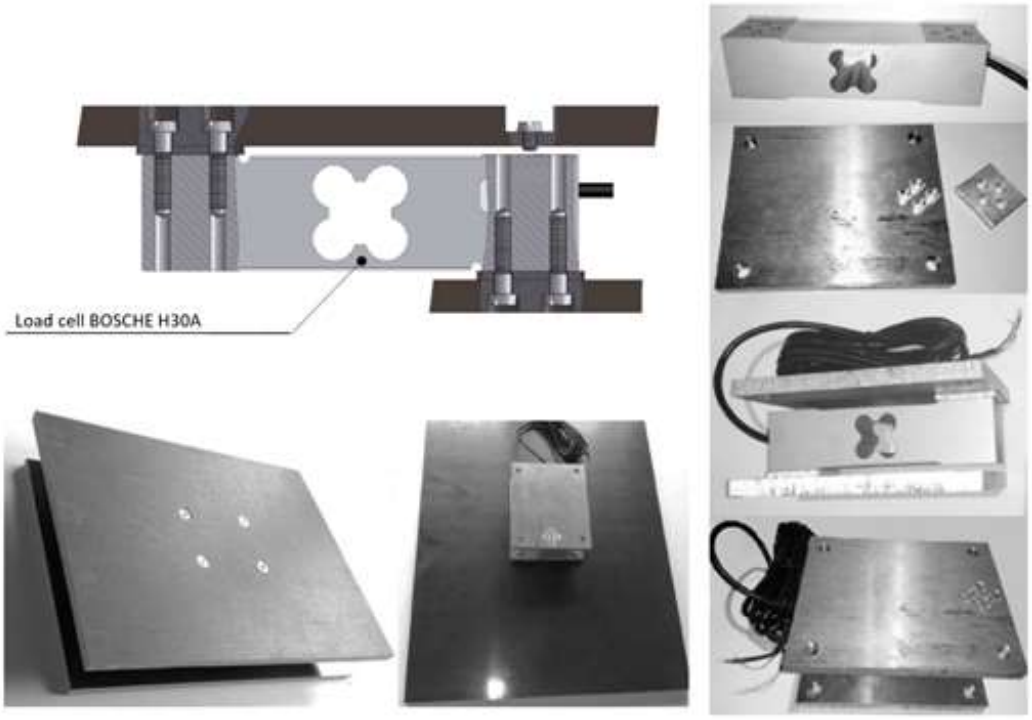

Figure 1. Load cell assembling process

Table 1. System components with unit costs

Nr.	**Name of the component**	**Cost (in EUR)**
1	BOSCHE Wagetechnik Single point load cell H30A (200kg)	50.00
2	Platform for load cell	50.00
2.1	Plywood	*14.00*
2.2	Metal plate	*14.00*
2.3	Screws	*2.00*
2.4	Assembling costs	*20.00*
3	Raspberry Pi Zero W + SD card	22.00
4	Temperature sensor DS18B20	4.00
5	Humidity and temperature sensor DHT22	7.00
6	A/D converter Sparkfun HX711	11.00
7	3G router Huawei E5330	37.00
8	Additional components (breadboard, wires, connectors, etc.)	10.00

The costs for one developed system are 191.00 EUR. System installation, maintenance, data storage, SIM card with appropriate data plan and usage of the web system is not taken into account in those calculations. As well some

components are optional, like 3G router can be dismissed if there are Wi-Fi connection at the site.

Measurement intervals can be configured individually based on required information that should be gained from the system. In authors case, as system is powered from central power network measurement can happen more frequently that it would be needed in real situation. In authors case measurements are performed each 2 minutes.

Sensitivity tolerance of the chosen load cell is ±0.2 mV/V, which gives measurement error of ±1 g, nevertheless calibration with standard weight is necessary. This resolution is more than enough for the beekeepers, because during the active summer period hive weight changes can achieve 1-3 kg during the day.

LOAD CELL CALIBRATION PROCESS

For precise weight measurements load cell should be calibrated before placing the beehive on it. Calibration technically means to determine the difference between the scale readout and the actual weight on the weighing platform to determine accuracy. Calibration was performed placing an object with known weight on a scales, making several weightings and getting the needed offset and scale factor values.

For scales precision evaluation weighting experiment with known weights (5kg, 7.853 kg, 10kg, 17,853kg metal weight) using three physical weights of 5kg, 5kg and 7.853kg was performed in the laboratory. Ten measurements each two minutes was performed. Weights were placed at the centre of the scale platform. Overview of the test measurements are summarised in Table 2 below:

Table 2. Overview of the test weighing measurements

Id of the experiment	Known weight (g)	Average (from 10 readings) reading from the scales (g)	Error (g)	STDEV (g)	Error (%)
EXP-1	0	4,5	4,5	1,51	-
EXP-1	5000	5001,9	1,9	0,99	0,038
EXP-1	7853	7856	3	0,94	0,038
EXP-1	10000	10001	1	1,15	0,010
EXP-1	17853	17857,5	4,5	1,18	0,025

One of the possible problems with scales precision when using single point load cell could be when object is placed not in the centre but in some corner of the platform. To evaluate this, additional experiments are performed placing weights at different locations on the scale platform and making once again ten measurements each two minutes. Overview of the test measurements are summarised in Table 3 below:

Table 3. Overview of the test weighing measurements placing weights at different locations

Id of the experiment	Known weight (g)	Average (from 10 readings) reading from the scales (g)	Error (g)	STDEV (g)	Error (%)
EXP-2	17853	17848,9	-4,1	1,10	-0,023
EXP-3	17853	17864,4	11,4	0,84	0,064
EXP-4	17853	17877,1	24,1	1,52	0,135
EXP-5	17853	17858,1	5,1	1,45	0,029
EXP-6	17853	17855,9	2,9	0,88	0,016

Experiment set-up and location of weights is shown in Figure 2 below:

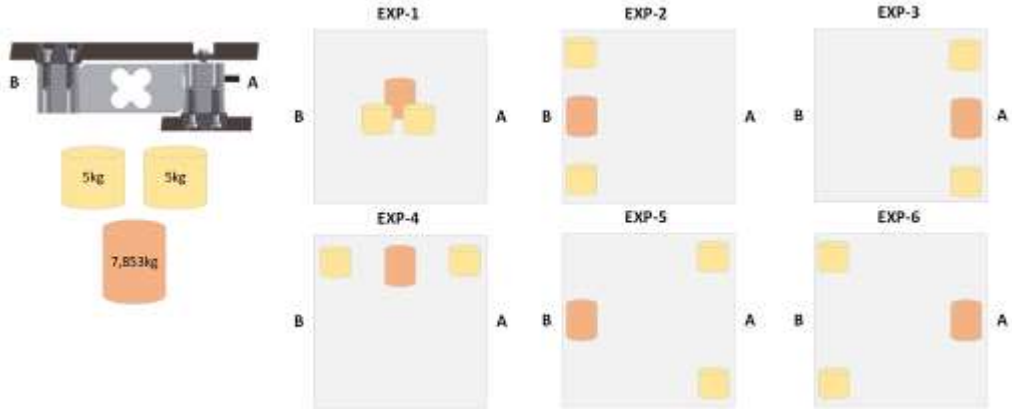

Figure 2. Location of weight on a scale platform during the weighting experiment

Analysing the measurements, it can be seen that there are minor changes in values depending on the placement of weight on a scale platform, but those can be considered as insignificant, as error is less than 1 %.

During the experiments it is found that any physical operation with scales, like lifting, changing its location affects the weighting values. Therefore, it needed to perform taring procedure each time scales are transported to a new location. For the beekeepers it is mean additional operation to perform before initial bee hive weighting. To make this process more user-friendly authors developed a physical interface for scale taring operation. Basically, additional button is connected to the system and when it is pressed system make taring operation.

Another issue found during lab experiments is weight fluctuation in relation to environmental temperature. With increase of the temperature weight is decreasing (see Fig. 3). Authors made a conclusion that A/D converter is affected by the temperature changes. It is confirmed by heating the A/D converter by the electric heater and monitoring the weight change.

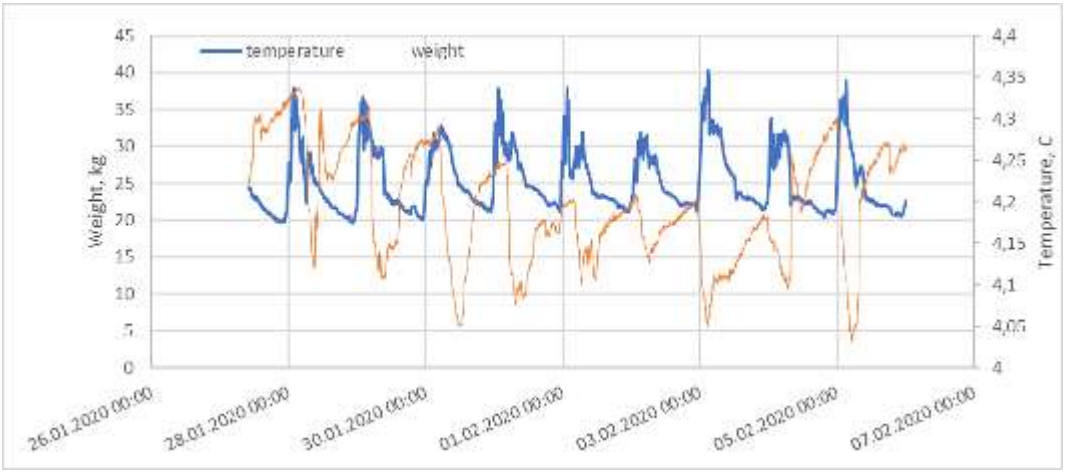

Figure 3. Relation of the weight measurements with environmental temperature

FIELD TESTS WITH DEVELOPED SYSTEM

After calibration, tests and experiments in laboratory system was installed in real environment to monitor two bee colonies during the passive wintering period. Practical experiments were conducted in the bee colony wintering building made from metal sandwich panels (Stalidzans et al., 2017) in the LLU apiary in Strazdu iela, Jelgava, Latvia. Colonies were placed in the wintering building on 21.01.2020. Figure 4 below demonstrates real placement of the developed system:

Figure 4. Installation of the system in real environment

For the measurement storage and analysis data management solution was developed. Authors called it data warehouse (DW). DW is developed with main aim to help beekeepers run the apiary more effectively by utilising higher amount of available data and accumulated data interpretation knowledge. DW architecture is developed considering flexibility and extensibility. Within the DW data visualisation is possible. Figure 5. below demonstrates chart with weight dynamic of the bee colonies:

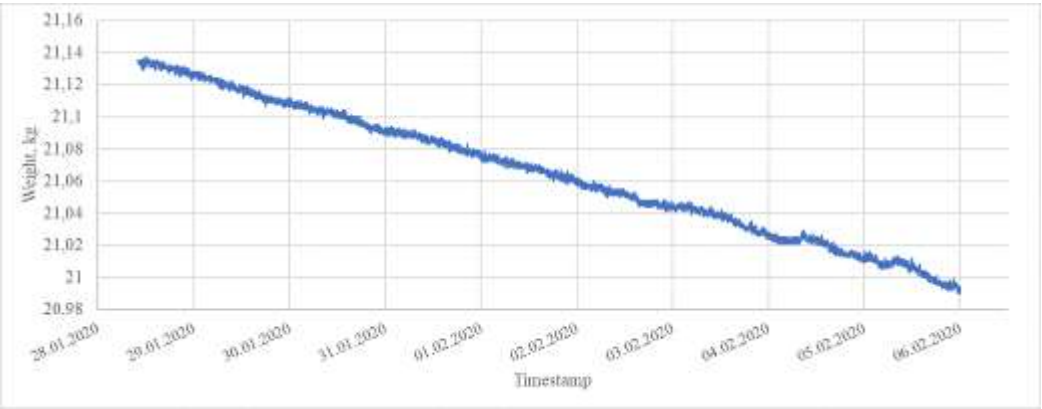

Figure 5. Weight dynamic of one bee colony

CONCLUSIONS

Continuous and real time monitoring of the bee colony main parameters like weight and temperature becomes a standard procedure in the beekeeping practice and acts as a first stage in implementation of the Precision Beekeeping approach.

Weight monitoring of at least one reference colony at the apiary can help to identify periods of the nectar flow and predict the colony foraging activity.

Developed system should be used to minimise the number of manual bee colony inspections, which should lead to the minimisation of stress to the bee colony.

Proposed honey bee weight and temperature monitoring system uses one load cell for weight measurements, very accurate (± 0.4 °C) two temperature sensors and Raspberry Pi for data collection from the sensors and transferring it to the remote data warehouse. In a future system can be set up also in a remote area, when alternative power supply and mobile network capabilities will be integrated.

Developed system could also be extended with additional functionality adding new sensors for example for detection of hive openings, or detection of other disturbances (e.g, hives can be damaged by animals).

ACKNOWLEDGMENT

Scientific research, publication and presentation are supported by the Horizon 2020 Project SAMS ‘Smart Apiculture Management Services’. This project receives funding from the Horizon 2020 European Union Research and Innovation Framework under Grant Agreement Nr.780755 – SAMS.

REFERENCES

Bradbear, N. (2009). "Bees and their role in forest livelihoods" A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. *Food and Agricultural Organization of the United Nations*, *19*, 194. https://doi.org/10.1017/CBO9781107415324.004

Breeze, T. D., Bailey, A. P., Balcombe, K. G., & Potts, S. G. (2011). Pollination services in the UK: How important are honeybees? *Agriculture, Ecosystems & Environment*, *142*(3–4), 137–143. https://doi.org/10.1016/j.agee.2011.03.020

Buchmann, S., & Thoenes, S. (1990). The electronic scale honey bee colony as a management and research tool. *Bee Science*, *1*, 40–47. Retrieved from http://www.cabdirect.org/abstracts/19910229804.html

Cecchi, S., Terenzi, A., Orcioni, S., Spinsante, S., Mariani Primiani, V., Moglie, F., Isidoro, N. (2019). Multi-sensor platform for real time measurements of honey bee hive parameters. *IOP Conference Series: Earth and Environmental Science*, *275*, 012016. https://doi.org/10.1088/1755-1315/275/1/012016

Crane, E. (1990). *Bees and beekeeping: science, practice and world resources*. Heinemann Newnes.

Fitzgerald, D. W., Edwards-Murphy, F., Wright, W. M. D., Whelan, P. M., & Popovici, E. M. (2015). Design and development of a smart weighing scale for beehive monitoring. *2015 26th Irish Signals and Systems Conference, ISSC 2015*, 1–6. https://doi.org/10.1109/ISSC.2015.7163763

Gil-Lebrero, S., Quiles-Latorre, F., Ortiz-López, M., Sánchez-Ruiz, V., Gámiz-López, V., & Luna-Rodríguez, J. (2016). Honey Bee Colonies Remote Monitoring System. *Sensors*, *17*(12), 55. https://doi.org/10.3390/s17010055

Human, H., & Brodschneider, R. (2013). Miscellaneous standard methods for Apis mellifera research. *Apicultural Research*, *52*(4), 1–53.

Komasilovs, V., Zacepins, A., Kviesis, A., Fiedler, S., & Kirchner, S. (2019). Modular sensory hardware and data processing solution for implementation of the precision beekeeping. *Agronomy Research*, *17*(2), 509–517. https://doi.org/10.15159/AR.19.038

Kremen, C., Williams, N. M., & Thorp, R. W. (2002). Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences of the United States of America*, *99*(26), 16812–16816. https://doi.org/10.1073/pnas.262413599

Kviesis, A., & Zacepins, A. (2015). System Architectures for Real-time Bee Colony Temperature Monitoring. *Procedia Computer Science*, *43*, 86–94. https://doi.org/DOI: 10.1016/j.procs.2014.12.012

Lecocq, A., Kryger, P., Vejsnæs, F., & Jensen, A. B. (2015). Weight watching and the effect of landscape on honeybee colony productivity: Investigating the value of colony weight monitoring for the beekeeping industry. *PLoS ONE*, *10*(7). https://doi.org/10.1371/journal.pone.0132473

McLellan, A. (1977). Honeybee colony weight as an index of honey production and nectar flow: a critical evaluation. *Journal of Applied Ecology*, *14*, 401–408. Retrieved from http://www.jstor.org/stable/2402553

Meikle, W. G., & Holst, N. (2015). Application of continuous monitoring of honeybee colonies. *Apidologie*, *46*(1), 10–22. https://doi.org/10.1007/s13592-014-0298-x

Meikle, W., Hoist, N., & Mercadier, G. (2006). Using balances linked to dataloggers to monitor honey bee colonies. *Journal of Apicultural Research*, *45*, 39–41. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=17873767

Nightingale, J. M., Esaias, W. E., Wolfe, R. E., Nickeson, J. E., & Ma, P. L. A. (2008). Assessing Honey Bee Equilibrium Range and Forage Supply using Satelite-Derived Phenology. *IGARSS 2008 - 2008 IEEE International Geoscience and Remote Sensing Symposium*, III-763-III–766. https://doi.org/10.1109/IGARSS.2008.4779460

Ochoa, I. Z., Gutierrez, S., & Rodriguez, F. (2019). Internet of Things: Low Cost Monitoring BeeHive System using Wireless Sensor Network. *2019 IEEE International Conference on Engineering Veracruz (ICEV)*, 1–7. https://doi.org/10.1109/ICEV.2019.8920622

Odoux, J.-F., Aupinel, P., Gateff, S., Requier, F., Henry, M., & Bretagnolle, V. (2014). ECOBEE: a tool for long-term honey bee colony monitoring at the landscape scale in West European intensive agroecosystems. *Journal of Apicultural Research*, *53*(1), 57–66. https://doi.org/10.3896/IBRA.1.53.1.05

Partap, U. (2011). The pollination role of honey bees. In *Honey bees of Asia* (pp. 227–255). Berlin: Springer.

Sengul Dogan, Erhan Akbal, G. ozmen koca. (2017). Design of a Remote Controlled Beehive for Improving Efficiency of Beekeeping Activities. *8th International Advanced Technolohies Symposium*, (November), 1084–1090.

Simon-Delso, N., San Martin, G., Bruneau, E., Minsart, L.-A., Mouret, C., & Hautier, L. (2014). Honeybee Colony Disorder in Crop Areas: The Role of Pesticides and Viruses. *PLoS ONE*, *9*(7), e103073. https://doi.org/10.1371/journal.pone.0103073

Stalidzans, E., Zacepins, A., Kviesis, A., Brusbardis, V., Meitalovs, J., Paura, L., … Liepniece, M. (2017). Dynamics of Weight Change and Temperature of Apis mellifera (Hymenoptera: Apidae) Colonies in a Wintering Building With Controlled Temperature. *Journal of Economic Entomology*, tow282. https://doi.org/10.1093/jee/tow282

Terenzi, A., Cecchi, S., Spinsante, S., Orcioni, S., & Piazza, F. (2019). Real-time System Implementation for Bee Hives Weight Measurement. *2019 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor)*, 231–236. https://doi.org/10.1109/MetroAgriFor.2019.8909252

Zabasta, A., Zhiravetska, A., Kunicina, N., & Kondratjevs, K. (2019). Technical Implementation of IoT Concept for Bee Colony Monitoring. *In 2019 8th Mediterranean Conference on Embedded Computing (MECO)*, 1–4. https://doi.org/10.1109/meco.2019.8760180

Zacepins, A., Pecka, A., Osadcuks, V., Kviesis, A., & Engel, S. (2017). Solution for automated bee colony weight monitoring. *Agronomy Research*, *15*(2), 585–593.

Zacepins, A, Jelinskis, J., Kviesis, A., Dzenis, M., Komasilovs, V., & Komasilova, O. (2018). Application of LoRaWAN technology in Precision Beekeeping. *IX International Scientific Agriculture Symposium "AGROSYM 2018", Jahorina, Bosnia and Herzegovina, 4-7 October 2018. Book of Proceedings*, pp. 1759–1765.

Zacepins, Aleksejs, Brusbardis, V., Meitalovs, J., & Stalidzans, E. (2015). Challenges in the development of Precision Beekeeping. *Biosystems Engineering*, *130*, 60–71. https://doi.org/10.1016/j.biosystemseng.2014.12.001

Zetterman, B. E. A. (2018). *Beekeepers usage of IoT*. Data collection, sharing and visualization in the domain of beekeeping. Master Thesis, Linnaeus University, 64p.

Original Scientific paper
10.7251/AGRENG2002056B
UDC 633:631.67]:631.16

ECONOMIC VALUATION OF SURFACE IRRIGATION WATER: SHIRE VALLEY, SOUTHERN MALAWI

Esau BANISI[*1], Julius MANGISONI[2], Davies NG'ONG'OLA[2], Sika GB'EGB'EL'EGB'E[3], Kennedy MACHILA[2]

[1]Department of Irrigation, Lilongwe, Malawi
[2]Department of Agriculture and Applied Economics, Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
[3]International Institute for Tropical Agriculture, Lilongwe, Malawi
*Corresponding author: esbanisi@yahoo.com

ABSTRACT

Economic valuation of surface irrigation water and the factors that determine willingness to pay for such resource for sustainable purposes is not clearly defined in Malawi. This paper evaluated economic value of surface water used in irrigation and identified factors influencing farmers' decision to participate in water markets for rice and sugarcane production in Upper Shire Valley of Southern Malawi. A cross-sectional data from 310 households involved in irrigation activities was used. General Algebraic Modelling System (GAMS) was employed to determine the economic value of surface water. Craggit Double Hurdle Model and Range-WTP procedure was employed to determine factors influencing farmers' decision to participate and pay for surface water solicit the social value of the surface water. The results revealed an economic value of 480.77 Malawi Kwacha[1] (MK)/m^3 for surface water in the valley, but specifically pointed out that surface water value for rice and sugarcane production was MK 512.96/m^3 and MK 448.58/m^3 respectively. Households irrigating rice and sugarcane revealed a willingness to pay for water at MK 1.67/m^3 and MK 2.87/m^3 respectively. Farming as a livelihood, plot status, crop type and market prices are reported to be influencing household participation in the water market. The study recommends that: (i) Farmers must always be informed of the economic value of irrigation water and be prepared to pay for it; and (ii) The allocated land should have a well-defined period of access and crop types to be grown in the valley should be of high economic value.

Key Words: *Economic valuation, Craggit Double Hurdle Model, Irrigation water, Sugarcane, Rice.*

[1] 1US$=MK720.12 www.exchange-rates.org. Accessed on 17th April, 2019

INTRODUCTION

Water is increasingly becoming scarce all over the world (UN-WAP, 2017) while its demand is continuously increasing due to the expanding population and rising prosperity, changes in diet (Syaukati *et al.*, 2014) and climate change (Samarawickrema and Kulshreshtha, 2009). Due to its unique characteristics, water is very important natural resource in agriculture for prosperity and wealth creation (Kiprop *et al.*, 2015; Karthikeyan, 2010). FAO (2003) estimated that more than 70 percent of water withdrawn from rivers is used for irrigated agriculture and increases beyond 80 percent in Sub Saharan countries (Angola, Ghana, Lesotho, Malawi, South Africa, Zimbabwe, Botswana, Zambia).

The rising population (NSO, 2018) and the huge investment in new irrigation development of 42,500 hectares supported by the World Bank (GoM, 2017) in the Upper Shire Valley mean that available water resources have to be managed properly. The current water management challenges in the Upper Shire Valley is attributed to several management (water pricing, distribution), natural (water availability, drought; flooding) and socio economic (poor access to water, inappropriate water pricing strategies, poor infrastructure management constraints (FAO, 2003). Hence, it is vital that optimal and sustainable forms of water use be established to meet the requirements of a growing population. By finding the economic value of surface irrigation water, we attempt to provide necessary guidance to stakeholders involved in irrigated agriculture by promoting water resource management and reduce water-related conflicts.

Description of the Upper Shire Valley Basin

The Upper Shire Valley is located in the Southern part of Malawi. It boasts of large commercial agriculture (sugar and rice) areas supporting more than half a million people (GoM, 2017). The valley often experiences warm-wet season which stretches from November to April, during which 95% of the annual precipitation takes place. Annual average rainfall varies from 725mm to 2,500mm. A cool, dry winter season is obvious from May to August with temperatures varying between 17 - 27°C. In addition, frostiness may occur in isolated areas in June and July. A hot, dry season lasts from September to October with average temperatures varying between 25 and 37 degrees Celsius. Humidity ranges from 50% to 87% for the drier months of September/October and wetter months of January/February, respectively (GoM, 2017).

The study was carried out in Nkhate Rice Irrigation Scheme, located in the Eastern Bank of the Shire River and Phata Sugarcane Scheme, located in the western bank of Shire River within the Valley. The sampled irrigation schemes have a total population of 2,117farmers (GoM, 2017). Nkhate Irrigation Scheme grows rice in its entire 300 hectares and has a population of 1,365 farmers. Phata Sugarcane Scheme grows sugarcane in its entire 250 hectares with a population of 752 farmers.

MATERIALS AND METHODS

Since economic activities are intended to maximize income subject to constraints of any given technology, households engaged in irrigated agriculture are faced with challenges of optimizing the available surface water to maximize profits. Data from 310 randomly selected farmers from two irrigation schemes is used in this study. Specific assumptions are made in various fields of study including economics so as to deduce sets of rules that must be followed to obtain certain results. As yield under irrigated agriculture is a function of irrigation at a time, other additional factors are crucial for production to take place and can be expressed as:

$$Y\ (I) = f(land, water, labor, seed, fertilizer, chemicals, implements, capital)$$

All factors that enter the production function are not known and may not be finite in number. When one specifies output as a function of $x_{1,}$ through x_n, one explicitly assumes factors $x_{n+1,}$to x_p are held constant if it is known that *p* factors affect production. Based on this logic and following Leemans and Born (1994), a *ceteris paribus* scenario is adopted in the study. The crop production function is then employed and takes a transcendental form of:

$$Y(I_t) = \propto I^{\beta} e^{-\gamma I}$$

where $Y(I_t)$ is yield which is a function of irrigation at time *t*, and *I* is the amount of irrigation water applied, while α, β, γ are constants and *e* is the exponential value. Following Hamsen (2000), water stock function is presented as:

$$R(S_t) = f\left(1 - e^{-g(K - S_t)}\right)$$

where: $R(S_t)$ is the stock flows in the river at time *t* which is an input for crop production. The right hand side is the amount of water present at that particular time *t*, implying that the more the water, the higher the yield and profit. Aggregating the crop production function and aquifer recharge function, gives a maximization problem presented as:

$$J(S_o) = \max_{I_t} \sum_{t=0}^{\infty} \left(\frac{1}{1+r}\right)^t \left[p_y \alpha I^{\beta} e^{-\gamma I} - p_e \left(\frac{I_t}{c S_t^b}\right)^a\right]$$

subject to:

$$S_0 = \bar{S}$$
$$S_{t+1} - S_t = f\left(1 - e^{-g(K - S_t)}\right) - I_t\ ;$$
$$t = 0, \ldots\ldots, \infty$$

Where, *J* measures the optimal value of the initial stock of water (S_o) in m^3. The right-hand side maximizes the net sum of discounted social net benefits from the total revenue realized from irrigation yield discounted at time *t*. The social discount

rate is given as $\left(\frac{1}{1+r}\right)^t$. Applying the maximum principle, solution is obtained by maximizing the Hamiltonian *H*, as follows:

$$H_t = (\tfrac{1}{1+r})^t \left[p_y \alpha I^{\beta} e^{-\gamma I} - p_e \left(\frac{I_t}{c S_t^b} \right)^a \right] + \lambda_{t+1} \left[f\left(1 - e^{-g(K-S_t)}\right) - I_t \right]$$

We further develop procedures to derive Willingness to Pay (WTP) which are essential for developing an optimal water pricing strategy (Balderjahn, 2003). A single household is considered in this study, and in order to improve utility of an environmental good, this household will adopt this equation:

$$Max_k\, U = U(k, w) \quad s.t \;\; I = p_k k + p_w w$$

where *U (.)* is the utility function, *k* is the composite of all market goods and *w* is the public good quantity. p_k and p_w are the prices of a market good and the public good (water), respectively, and *I* is the household income. Thus, with the demand functions derived from the utility maximization process, we can form the indirect utility function ($V(p_k, p_w, I)$ that matches with the utility function ($U(k, w)$ as:

$$V(p_k, p_w, I) = U[(d^x(p_k, p_w, I), d^w(p_k, p_w, I)]$$

It can be said that improved surface water flow to individual household plots is when field plots receive enough uninterrupted flow of good quality but at a minimum price. Therefore, a quantifiable quality or quantity *q*, will change from the current status quo (*q0*) to a new status (*q1*), where *q0< q1*. Subsequently, the households' utility function is expected to change from $U_0 \equiv v(p_k, p_w, I, q_0)$ to $U_1 \equiv v(p_k, p_w, I, q_1)$. Thus, to measure the change in utility in monetary terms, the Hicksian measure of Consumer Surplus Utility (CSU) is used:

$$V(p_k, p_w, I, q_0) = V(p_k, p_w, I - CSU, q_1)$$

A further change from quantity q_0 to q_1 raises the utility levels of a household regarded as improvement of water services. To make the household indifferent between the two utility levels, CSU need to be positive and in this case measures the households WTP presented as:

$$V(p_k, p_w, I, q_0) = V(p_k, p_w, I - WTP, q_1)$$

We then followed Syaukat, (2014) by modifying Hanley and Splash, (1993) formulation of the WTP procedure in order to solicit values farmers are willing to pay as follows:

i. Setting up a hypothetical market for irrigation water.
ii. Obtained open WTP values from each household, of which Range WTP was categorised into five parts (MK1,000-1,500; 1,500-2,500; 2,500-5,000; 5,000-10,000; 10,000-25,000)
iii. Estimate mean WTP,
iv. Derive total value of the WTP

We finally applied Craggit Double Hurdle Model to establish factors that influence farmers' participation in the water market follow the selectivity models (Zamasiya *et al*., 2014; Geoffrey *et al*., 2013). In selectivity models, the decision to participate is a sequential two-stage decision making process. In the first stage, farmers' make a discrete choice whether to participate in the payment of surface water fees. In the second stage, conditional on their decision to participate, households make continuous decisions on the extent of participation. Following Wooldridge (2002), a standard probit model which follows random utility model was based on and households' willingness to participate in the water market is then specified as:

$$WTP = \beta_0 + \beta_1 age + \beta_2 sex + \beta_3 education + \beta_4 livelihood + \beta_5 plotstatus + \beta_6\ plotstatus + \beta_7\ croptype + \beta_8\ marketprice + \epsilon_i$$

WTP is the probability that an *i*th household involved in irrigation is willing to participate in the water market; β_i is the coefficients of the explanatory variables; ϵ_i is the error term. The second hurdle which estimates the amount (fees) households are willing to pay is estimated using a regression truncated at zero, expressed as:

$$How\_much_i = How\_much_i^*\ if\ How\_much_i^* > 0, and\ How\_much_i^* = 0\ if\ otherwise$$

$$How\_much^* = \alpha_i'\beta + \mu_i$$

Where: How_much^* is the observed response on how much households are willing to pay for water fees; α is the vector of household, irrigation plot and institutional characteristics, β is a vector of parameters and μ_i is the error term which is randomly distributed.

RESULTS AND DISCUSSION

Results in Table 1 indicate that the economic value of surface water in the Upper Shire Valley is MK 480.77 per cubic meter. The results further reveal that the economic value of irrigation water in Nkhate Rice Scheme was MK 512.96 per cubic meter and MK 448.58 per cubic meter in Phata Sugarcane Scheme. This indicates that water is more valuable to produce rice than sugarcane in the valley. It also implies that for households to achieve optimal yields, they should manage properly water resources against other inputs unlike in sugarcane.

Table 1. Economic value of irrigation water

Irrigation Scheme	Economic value of irrigation water in a season [MK/ m^3]
Nkhate Rice Scheme	512.96
Phata Sugarcane Scheme	448.58
Overall water value	480.77

The test results revealed a *p*-value of 0.0143 implying that there is an economic value on irrigation water in the Upper Shire Valley. It therefore means that irrigation water in Nkhate Rice Scheme and Phata Sugarcane Scheme should be treated as an economic good which is supposed to be considered in coming up with economic efficient decisions. The findings are supported by similar studies conducted in the Southern Africa Region. Nieuwoudt *et al.* (2014), analyzed the value of water in the agriculture sector of the South African economy and observed that the economic value of irrigation water ranges from US$ 0.6/m^3 to US$2.10/$m^3$. The results in Table 2 show that 36 percent of the households had an expected mean WTP value of MK 316.11 in each season. The results further show that 23 percent had an expected WTP value of MK 341.67. This implies that more than half of the sampled households are willing to pay within the ranges of MK 316.11 and MK 341.67. Therefore, based on the sampled households, the average WTP was MK2, 355.56. According to FAO, (2003) irrigated lowland rice requires 16,500 cubic meters of water per hectare during a full season. Since Nkhate households are allocated an average of 0.1 hectare of land, it implies that each household was ready to pay an average of MK 1.67 per cubic meter of water. This is however, too low as compared to derived economic water value of MK 480.77/m^3 .

Table 2. WTP for water in Nkhate Rice Scheme in a season

WTP Category	**Range (MK/season)**	**Response Percentage**	**Expected Mean WTP (MK/season)**
1	1000-1500	36.1	361.11
2	1500-2500	22.7	341.67
3	2500-5000	21.6	541.67
4	5000-10000	16.6	833.33
5	10000-25000	2.7	277.78
Average WTP Value			2,355.56

According to Holden and McGuire (2010), irrigated sugarcane crop under sprinkler application requires a total of 1,000 cubic meters of water per hectare in a growing season. Since households are allocated an average of 0.5 hectare of land, it implies that households are willing to pay MK 2.87 per cubic meter of surface water. This willingness to participate and contribute differently in the water market was found to be influenced by livelihood main sources, plot status, crop type and market prices of crops produced by farmers

CONCLUSION

The study concludes that surface water for irrigation purposes in the Upper Shire Valley, Southern Malawi has mean economic value of MK 480.77/m^3. It therefore means that irrigation water in Nkhate Rice Scheme and Phata Sugarcane Scheme should be treated as an economic good which is supposed to be an input in all management decisions and plans. The smaller value of money farmers are willing to pay for water in the valley are too much below the established economic value as such sustainability of water management cannot stand. Unfortunately, water resources authorities allow farmers to abstract water even without settling their annual water fees. Since the study revealed that main livelihood as source of a household income, plot status and crop type are paramount in deciding participation and payment of water fees by farmers, priority in land allocation and crop types should be supported. The allocated land should have a well-defined period of access and crop types to be grown in the valley should be of high economic value.

ACKNOWLEDGEMENT

We are very grateful to NORHED through the Climate Smart Natural Resources and Agriculture Project (CLISNAP) for the financial assistance provided to conduct this study.

REFERENCES

Balderjahn, I., Der Preisbereitschaft, E., Diller, H. and Hermann, A. (2003). Handbook for Preispolitik: Strategies -Planning -Organization -Umsetzung, – Wiesbaden: Gabler. (387-404). In Renkema, M. (2011). Heracles Almero: University of Twente Student Theses.

Food and Agriculture Organization of the United Nations (2003). *Review of the World Water Resources by Country*. Water Report No.23; FAO: Rome, Italy.

Geoffrey, S.K., Hillary, B., Lawrence, K., Kibet, K. and Mutai, M.C. (2013). Determinants of market participation among small-scale pineapple farmers in Kericho County, Kenya. *Journal of Economics and Sustainable Development*, 4 (19): 59–67.

Government of Malawi (2017). Department of Irrigation Annual Report for 2015/17 financial Year. Lilongwe. (Unpublished).

Hanley, N. and Splach, C.N. (1988). *Cost Benefit Analysis and the Environment*. England. Edward Elgar Publishing Ltd.

Holden, J. R. and McGuire, P.J. (2010). Irrigation of Sugarcane Manual. Queensland, Australia. BSES Limited.

Karthikeyan, C. (2010). *Economic and Social Value of Irrigation Water: Implications for Sustainability*. Tamil Nadu Agricultural University Coimbatore, Tamil Nadu, India.

Kiprop, J.K., Lagat, J.K., Mshenga, P. and Macharia, A.M. (2015). Determining the Economic Value of Irrigation Water in Kerio Valley Basin by Residual Value Method. *Journal of Economics and Sustainable Development*, 6(7):102-107.

Leemans, R. and van den Born, G.J. (1994). Determining the potential distribution of vegetation, crops and agricultural productivity. *Water, Air, and Soil Pollution*, 76: 33-161.

National Statistics Office (2018). Malawi Population and Housing Census Report. National Statistics Office. Zomba.

Nieuwoudt, W.L., Backeberg, G.R. and Du Plessis, H.M. (2014). The value of water in the South African economy: some implications. *Agrekon*, 43 (2).

Samarawickrema, A. and Kulshreshtha, S. (2009). *Marginal Value of Irrigation Water Use in the South Saskatchewan River Basin*. Canada Alberta Research Council, University of Saskatchewan, Canada.

United Nations World Water Assessment Program (2017). *The United Nations World Water Assessment Report.Waste Water: The Untapped Resource.* Paris: UNESCO.

Zamasiya, B., Mango, N., Nyikahadzoi, K. and Siziba, S. (2014). Determinants of soybean market participation by smallholder farmers in Zimbabwe. *Journal of Development and Agricultural Economics*, 6 (2): 49-58.

Original Scientific paper
10.7251/AGRENG2002064P
UDC 637:636.4(469)

A PORK VALUE CHAIN IN PORTUGAL: THE CASE STUDY OF PORCO ALENTEJANO, MONTANHEIRA SYSTEM AND TRADITIONAL PRODUCTS

Maria João PARREIRA[1*], Fátima OLIVEIRA[2], Pedro REIS[1], Inocêncio COELHO[1]

[1]National Institute for Agricultural and Veterinary Research (INIAV I.P.), Oeiras, Portugal
[2]College of Agriculture, Polytechnic Institute of Coimbra (IPC, CERNAS), Coimbra, Portugal
*Corresponding author: mjoaoparreira@gmail.com

ABSTRACT

For the production of the *Porco Alentejano*, an autochthonous Portuguese porcine breed, the *Montanheira* system is a crucial process, corresponding to a period of an intensive pig´s fattening in the *Montado*. It occurs between October and March, where the pigs freely consume the acorns. *Montado* is an agro-forestry-pastoral Portuguese system created by the human intervention, which occupies a large part of the territory, being a source of unique products, as the cork and the acorn. *Montado´*s management is a complex process due to its susceptibility to disturbances of soil and *Quercus* trees, and a dynamic between the economic activities and the conservation of this system. The objective of this study is to estimate, along the value chain, the Gross Product of the acorn, the *Montanheira* pig value, and of the fresh meat and final processed products, protected designation of origin (PDO) products. From the secondary information about the *Montado* area, the *Porco Alentejano* herds, and with the information collected in the field works, we estimate and present the results. The pig is the most efficient animal in the acorn conversion, multiplying by ten the economic value of food animal resource. The transformation into high quality traditional PDO hams and shoulders increases about 50% the value of the *Porco Alentejano* reared in *Montanheira*. The joint between the *Montado* and the development of rural areas, where the studied animal rearing takes place, is a good example of the balance between the economy, the sustainability of natural resources and cultural heritage.

Keywords: *Porco Alentejano, Montado, Montanheira, PDO, Sustainability.*

INTRODUCTION

In Portugal, the *Montado* is the most prominent agroforestry system, a system of high natural value and of great extension, with predominance in the south of the country. According to the European classification proposed by the European Environmental Agency, the *Montado* is a High Nature Value Farming System

(Pinto-Correia *et al*., 2011). There are different typologies of *Montado* in an irregular continuum, where the type, density of trees and under-cover, vary without obvious limits, creating a unique landscape with a specific character (Lauw *et al.*, 2013). In addition to cork, an important product for the Portuguese economy, the *Montado* also supports ecological and socioeconomic opportunities, especially in less favoured areas. The production of the *Porco Alentejano* breed is one remarkable evidence of the potential associated with the *Montado*. In this work, we explore the valuation of the production-processing-marketing chain of products of unique quality and high economic value, such as hams (*presuntos*) and shoulders (*paletas*) from the Alentejo, Protected Designation of Origin (PDO) products. It is not possible to obtain quality features of traditional pork products from conventional intensive production systems, since they have intrinsic attributes recognized by quality schemes and represent one culinary heritage of specific regions (Candek-Potokar *et al*., 2018). The creation of the *Montanheira* pig felt a sharp decline in the 1960s, due to health problems (African swine fever), but revived at the end of the last century and revealed great dynamism at the beginning of the 21st century. Its profitability is strongly dependent on the quality of the products obtained from *the Porco Alentej*ano, fattened mainly with acorn, well expressed in the five PDO products (four hams and palettes and one for fresh meat) and twenty-three Protected Geographical Indication (PGI) sausages. The aim of this work is to contribute to the understanding of the value added dynamics along the *Alentejano* Pork (*Porco Alentejano*) value chain, pointing out key issues that may stimulate multi-stakeholder processes for problem solving and sustainable farming practices, key drivers for rural prosperity.

MATERIALS AND METHODS

We follow the methodology of Coelho (2010), complementing with actual data. From the secondary information with official data about the *Montado* area, the *Porco Alentejano* herds, and, with the primary data from actors in the production and industry sectors, we made our estimations along the value chain. Overall, we estimate the value creation associated with the potential value (in euros) of the resource acorn, in the *Montanheira* fattening period, with the respective estimated potential number of pigs produced by each production cycle and its own potential value, and the value associated with the industrial transformation of the *Alentejano* Pork traditional products. For the calculation of the forest area with cork oaks and holm oaks by municipalities, the information available was used in field data referring to the years 1995 and 1998, since it was not possible to obtain more recent data in that area. The areas of *Montado* in the 185 municipalities of Portugal were calculated using the 4th national forest inventory (ICNF, 2019), as also for the *Montanheira* area, the delimited area of PDO products (meat, hams and palettes). It is necessary to consider that not all areas of Cork tree (*Quercus suber*) and Holm tree (*Quercus ilex* L. *ou Ballota*) surface are *Montado* areas. Thus, we had to apply coefficients

based on secondary information. The *Montado* surface (cork oak trees) represents about 70% of the total cork oak area in Portugal (Costa and Pereira, 2007). Regarding holm, the areas of holm oak forest represent 2% of this forest species (Onofre, 2007). For the calculation of the *Montado* area for each species, we applied a coefficient of 0.7 and 0.98, respectively, in the cork oak and holm oak areas. After determining the national areas of *Montado* with the two species of *Quercus*, we estimated the corresponding delimited area for the production of pigs and the transformation into DOP products (fresh meat, hams and palettes). We evaluated those *Montado* areas with the support of the national PDO product specification document and the IFN4 data (ICNF, 2019), correlating the specific areas. Then, we assess the number of potential pigs in each production cycle and the monetary value of the *Montado*, two key steps to quantify the potential acorn value. As some producers are the owners of the *Montado* and others just rent it, to determine the *Montado* value we consider the average price by hectare that the pig producers pay for the rent of the *Montado*, that is the *Montanheira* rent (€) paid by each fattened pig. We estimate the Gross Product at basic price, the Gross Value Added (GVA) at the primary production level, i.e. at the *Alentejano* herd rearing in *Montanheira*, and the GVA of the industrial part, i.e. concerning the final products obtained after processing such as PDO hams (*Presunto*), palettes (*Paleta*) products, and other sausages products, recognized for their high quality. The Gross Product and the GVA of the pig breeding, under the *Montanheir*a system were estimated based on the results of the survey carried out with 50 breeders, from the Association of South *Alentejano* Pig Breeders (ACPA - *Associação de Criadores de Porco Alentejano*) in the 2005/2006 campaign. Those survey results also allowed us to determine the animal head on *Montanheira*. To apply this methodology we assume that in the last decade there have been no significant changes in the technical itinerary. Thus, considering the maintenance of technical intentions, it would only be necessary to determine the current prices. For this determination, we used the current quotations of animals and the Consumer price index in the intermediate goods of agricultural production. For the pigs prices at producer level, we apply the values presented in the Agricultural Market Information System, SIMA - *Sistema de Informação de Mercados Agrícolas* (GPP, 2019). To determine the price indices, we applied the indicators of the agroforestry complex, produced by the Office of Planning, Policies and General Administration (GPP, 2019). To calculate the Gross Product and the GVA industry, we used the technical coefficients provided by the meat processor *Alentejano* pork with PDO scheme quality certification located in the *Alentejo*, called Montaraz (Coelho, 2010).

RESULTS AND DISCUSSION

The total forest area in Portugal with cork and holm oaks is 1,128,788 hectares (ha), 715,913 ha with cork oak and 412,875 with holm oak. Applying the coefficients collected in secondary sources, we obtain a total of a Montado area of 905,757 ha, 501,139 ha with cork oaks and 404,618 with holm oaks. Of the 185 forest counties in Portugal, 65 counties belong to the delimited regions of the *Porco Alentejano* value chain in Alentejo, concerning the production, transformation and distribution of the traditional PDO *Alentejano* pork products.

The potential of *Montado* areas delimited by the PDO *Alentejano* pig are for the holm and cork oak, 450,830 ha and 394,983 ha, respectively, in a potential total area of 845,813 ha. The area of holm and cork oak, correlated with the area of denomination of protected origin of the pig Alentejo products and fresh meat PDO, corresponds to 98% of the national area of holm oak and 90% of the national cork oak area. It is interesting to note that although the holm oak represents 37% of the national forest and 45% of the national *Montado* in the studied region (PDO *Alentejano* pork), its representativeness in relation to the national total of the *Montado* is higher than that of the *Montado* cork oak. In the holm oak *Montado,* 2.9 hectares are needed to feed a pig and in the Cork oak *Montado* this value is 4.8 hectares.

The calculated values, according to the obtained primary data, are in accordance with the values obtained in Passarinho *et al.* (2019) and Coelho (2010). Those hectares values by head were vital to estimate the potential number of finished pigs - *230,123 pigs*. To estimate the potential value (in euros) of the resource acorn, we applied the *Montanheira* rent (€) paid by each fattened pig, between 50 to 70 euros per head, which depends on the state of *Montado* (Freire, 2017). We considered the average value of 60 euros per head. Taking this value as a market reference value, the Potential Gross Product of the Acorn will be *13.8 million euros*. In order to be able to estimate the value of certified *Porco Alentejano* traditional products, it is necessary to consider two different production processes. One, the breeding with the aim to produce meat for processed products, namely Ham (*Presunto*) and Pork Pallet (*Paleta*), both PDO products. The other, the breeding with the purpose to produce meat, for fresh consumption, also with PDO certification. The pig bred for the production of meat for processing into Ham and Pallet will make the process of fattening in a full range in *Montanheira*. According to the data collected in the field, these pigs reach an average live weight of 170 kg. According to Grave (2015), the carcass yield is around 80%, that is, the pigs will present a carcass weight in average values of 135 kg. For the production of fresh meat, pigs do not make the complete fattening process in *Montanheira* and reach average carcass weights of about 65 kg. For the appreciation of pork prices in *Alentejo*, we consulted and applied the prices of SIMA, between January 2017 and July 2019, for each typology of pig production. For the production of processed products (hams and pallets), the average price obtained was 4.00 Euros / kg. In the case of

pork for meat fresh consumption, the average price in the period referred to was 3.13 Euros/kg. Thus, for the estimated potential of *230,123 pigs*, the Potential Gross Product of the *Alentejano* pork for the production of hams and pallets with PDO certification will be *124,266 million Euros*.

To obtain the same potential associated to the animals for the production of PDO fresh meat, first, we obtain a coefficient of 0.10 pigs/ha destined for meat for fresh consumption, according to the ACPA surveys data. Applying the *Montado* area, we estimated the potential production of *84,581 pigs*, for the production of fresh meat with PDO certification. Considering the price of meat per kilogram, we obtain the potential value of *Alentejano* pork for fresh meat production of *17,208 million euros*. Summing up, the Potential Gross Product of the certified *Alentejano* pork considering the two types of production, i.e. animals for meat production for the production of processed products and animals for fresh production, is *141,474 million euros*, corresponding the Gross Product of acorn (*13.8 million euros*) about 10% of that potential. To estimate the potential value of the Gross Added Value for *Alentejano* Pork with PDO certification, it is necessary to calculate an indicator between the Gross Added Value (GVA) and the Gross Production (GP). That is, that indicator helps to obtain the real weight of intermediate inputs in production, through the values presented by the producers. This relationship is obtained by applying the GVA value and the production value indicated in the survey mentioned above, carried out by ACPA. In order to update prices, the Implicit Price Index (IPI: Base 2011) for the production and intermediate inputs was applied (GPP, 2019). The weight of intermediate inputs will allow to obtain the Gross Added Value in relation to the Pork Gross Product Potential previously calculated, which was *141,474 million Euros***.** The Potential Gross Value Added of the *Altentejano* Pork with certification of origin will be 45.8% of 141,746 million Euros i.e. the *Potential GVA of Alentejano Pork* with PDO will be *64,795 million Euros*. The processing of the *Alentejano* pigs allows obtaining a varied set of processed products, hams, pallet and other processed products, namely sausages. In the value chain of *Porco Alentejano*, we must not only consider the value of products processed with PDO certification, but also the value of other processed products with PGI certification of origin, such as sausages. The prices presented were those collected in Coelho's work (2010), updating through the Consumer price index (annual average) for food products and beverages, CPI: 109.9, (GPP, 2019) The total value of processed products obtained through the processing of *230,123* pigs raised in *Montanheira* was estimated in *252,376 million euros*. About 73% of that total value corresponds to the production of Ham (*presunto*) and Palette (*paleta*) with PDO, *184,559 million euros*. If we consider the potential value of the *Montanheira* pigs for Ham and Pallets, estimated in 124,266 million euros, with the total potential value of the industry, *252,376 million euros*, we conclude the industrial transformation represents an increase, in relation to the value of the pig, of around 103%. If we consider just the potential industrial value for hams and palette (*184,559 million euros*), the transformation into high quality traditional PDO hams and shoulders increases about 50% the value of the *Porco*

Alentejano reared in *Montanheira*. These values are close to those previously obtained by Coelho (2010). It is important to highlight the values of the Gross Added Value associated with the production of the *230,123* pigs that it is *64,795 million Euros* and the GVA industry of *128.11 million euros*. They represent important values for the value chain of *Alentejano* Pork, summarized in the figure 1. Since the transformation phase is a great ally in the creation of the value added, it will be important to invest and improve the infrastructure and capacity of this industry. Portugal is still very dependent on Spain, as most of the *Montanheira* pigs, are sold to the neighboring country in the end of the fattening period. On the one hand, because it has no industrial capacity to transform the produced animals. On the other hand, because the production of this type of traditional products (hams and palettes) is very time-consuming and requires a lot of investment, one of the weaknesses of many entrepreneurs, with little financial capacity and without direct support. In addition, the acorn is a crucial resource and represents the beginning of this value chain, being an endogenous natural resource and vital for the valorization of these products, which are highly valued by the consumer. This resource currently faces great challenges related to the decline of the grove (phytosanitary problems), the need for more regeneration and thickening of the grove, associated with the soil's edaphoclimatic problems, low organic matter content, thin soils, frequency and severity of the drought periods. Yet, the holm oak values the pastures, given the greater nutritional value of the acorn in relation to the broadleaf, and more prominently when the production of the *Montanheira* pig is present on the farms. The *Alentejano* pig allows gross margins, without subsidies, higher than sheep, goats or cattle (Coelho and Reis, 2009), being fundamental for the conservation of the *Montado*, allowing the creation of an expressive added value for the economy of land owners, breeders and industry of processed pork products (Coelho, 2010).

Figure 1. Summary of the national potential related to the *Alentejano* Pork value chain

	Potential Number of Pigs	*Montanheira* Rent (€)	Potential Gross Product	Potential Gross Product
Montado PDO area (cork oak): **450,830 ha**		**60 € / fattened pig**	**Total: 141,474 M€**	**Total: 252,376 M€**
Montado PDO area (holm oak): **394,983 ha**			Hams and Palettes: 124,266 M€	Hams and Palettes: 184,559 M€
4.8 ha / pig (cork oak)	93,922 pigs		Fresh Meat: 17,208 M€	
2.9 ha / pig (holm oak)	136,201 pigs	**Potential Gross Product**	Potential Gross Value Added	Potential Gross Value Added
Total PDO area: 845,813 ha	**Total: 230,123 pigs**	**Total: 13,8 M€**	**64,795 M€**	**128,110 M€**

Source: Own elaboration

CONCLUSION

In Portugal, there are few works in the field and context of this work, which may stimulate a better understanding of the involved socioeconomic challenges. The joint between the *Montado* and the development of rural

areas, where the studied animal rearing takes place, is a good example of the balance between the economy and the sustainability of natural resources, the gene pool maintenance, cultural heritage and identity preservation. The *Porco Alentejano* breed allows high yields for the economic agents in the value chain, but the respective profitability is very sensitive to the management of the *Montado* and the disposable income of the stakeholders, consumers included. From the consumer's perspective, it is crucial to ensure the guarantee of authenticity of the products, as the consumer is willing to pay a premium for products of exceptional quality, being trust an essential value and an attribute to assure. For example, a Lamego ham can be purchased at € 10 / kg, while a Barrancos DOP ham can reach a retail price of over € 100 / kg. We stress the need to achieve the true potential of the Geographical Indications (GIs), as PDO and PGI products. It will be not enough to implement GIs, since they may be registered but not activated in the market, as for instance at the production or marketing levels. Long-term vision is vital as well as a cohesive articulation between the several efforts developed by the involved stakeholders, both at the regional, national and international levels. We highlight the need to develop future works in the following key challenges issues: Innovation *versus* (vs.) Differentiation, Orientation for Sustainability, Cooperation vs. Partnership, Investment vs. Market Orientation, Outreach activities and Science Communication efforts, Risk Management throughout Processes, National and International Contracts vs. Legal Frameworks. It is urgent to deepen understanding and integrate those issues, to help to cover the whole value system in which stakeholders operate. To be able to design and apply strategic actions that lead to rural prosperity, it will be vital to articulate those challenges, effectively and more efficiently, to achieve the desired competitive position and sustainability.

ACKNOWLEDGMENTS

This research was conducted within Project REALMed by ARIMNet2-2014-2017, ERA-NET coordinator by INRA-France funded by the 7th European Union Framework Program for Research, Technological Development and Demonstration under project – FCT: ARIMNET2/0005/2016.

REFERENCES

Candek-Potokar, M., Giusto, A., Conti, C., Cosola, C., & Fontanesi, L. (2018). Improving sustainability of local pig breeds using quality labels–case review and trademark development in project TREASURE. Archivos de zootecnia (1), 235-238.

Coelho, I. S. (2010). Economia da Montanheira, multifuncionalidade dos sistemas e sustentabilidade dos montados [Economy of Montanheira, multifunctionality

of systems and sustainability of montados]. In: Pastos: fuente natural de energía: 4ª Reunión Ibérica de Pastos y Forrajes, 3-6 May 2010, Zamora-Miranda do Douro. pp. 543-548.

Coelho, I. and Reis, P. (2009). Pastoralismo Mediterrâneo: competitividade, sustentabilidade dos territórios e diversificação da economia rural [Mediterranean pastoralism: competitiveness, sustainability of territories and diversification of the rural economy]. Pastagens e Forragens, 29/30: 99-11.

Costa, A. and Perreira, H. (2007). Montados e sobreirais: uma espécie, duas perspectivas.[Montados and cork oak trees: one species, two perspectives] In: Silva, J. (ed.), Os Montados – muito para além das árvores. Lisboa: Jornal Público, Fundação Luso-Americana para o Desenvolvimento, Liga para a Protecção da Natureza: 17-37.

Freire, E. (2017). Conheça o negócio do porco preto. [Get to know the black pork business.] Vida Rural. https://www.vidarural.pt/insights/conheca-negocio-do-porco-preto/. Accessed in 27/11/2019.

GPP (2019). Forest Complex Indicators. http://www.gpp.pt/images/Agricultura/Estatisticas_e_Analises/Indicadores_CAF/IndicadCAF_EstatProdConsVAB_CImai2018.pdf. Accessed on 27/10/2019.

Grave, M. (2015). Características da carcaça em suínos de raça Alentejana e cruzados Large White x Landrace terminados em montanheira. [Carcass characteristics in Alentejano and Large White x Landrace crossbred pigs finished in montanheira.] Dissertação para obtenção do Grau de Mestre em Engenharia Agronómica: Especialidade Agro-Pecuária, Instituto Superior de Agronomia, Universidade de Lisboa.

ICNF (2019) IFN6,6º Inventário Florestal Nacional. [6th National Forest Inventory], http://www2.icnf.pt/portal/florestas/ifn/ifn6. Accessed on 27/11/2019.

Lauw, A., Gonçalves-Ferreira, A., Gomes, A., Moreira, C., Fonseca, A., Azul, A. and. T Pinto-Correia, T., Ribeiro, N., Potes, J., (2013). Livro Verde dos Montados.[Montado Green paper], ICAAM -Instituto de Ciências Agrárias e Ambientais Mediterrânica, Évora, Portugal.

Onofre, N. (2007). A fauna dos montados de azinho. In: Silva, J. (ed.), Os Montados – muito para além das árvores.[The Montado - far beyond the trees.] Lisboa: Jornal Público, Fundação Luso-Americana para o Desenvolvimento, Liga para a Protecção da Natureza, 2007: 131-159.

Passarinho, J., Calha, I., Moreira, A (2019). Montado: Produção de bolota e silvopastorícia. [Montado: Acorn and silvopastoral production.] Dossier Técnico da Vida Rural, abril. 42-45, http://www.iniav.pt/fotos/editor2/montado_producao_de_bolota.pdf. Accessed in 27/11/2019.

Pinto-Correia, T., Ribeiro, N. and Sá-Sousa, P. (2011). Introducing the montado, the cork and holm oak agroforestry system of Southern Portugal. Agroforestry Systems, 82(2), 99. doi: 10.1007/s10457-011-9388-1

Original Scientific paper
10.7251/AGRENG2002072P
UDC[633.1:633.31/.37]:636.085.52

SILAGE YIELD AND PROTEIN CONTENT OF FORAGELEGUMES INTERCROPPING WITH CEREALS

George PAPANAOUM, Elissavet BOULOUMPASI, Theano B. LAZARIDOU*

University of Western Macedonia - Florina, School of Agricultural Sciences 53100 Florina, Greece
*Corresponding author: thelazaridou@yahoo.gr

ABSTRACT

Intercropping of most annual legumes with winter cereals is a very common practice for forage production in many countries. The aim of this study was to determine the effect of intercropping cereals with forage legumes on silage yield and protein content. The completely randomized design was applied with three replications and the experiment was established in the farm of the Western Macedonia University in Florina. Particularly, common vetch, forage pea and faba beans were used as forage legumes, and barley, bread wheat and triticale were used as cereals, which were grown individually as well as intercropped with each other in mixed rows in a sowing ratio 65:35. The plots consisted of seven rows five meters long of which the five inner were harvested. A total of 45 experimental plots was installed. The field was fertilized only with base fertilization. All the cultural practices used by farmers were applied. The plants were harvested when the legumes were at the end of the flowering period and were dried naturally for the formation of hay. The plants were separated by hand to determine the weight of fresh matter for each species. Samples of 100 g of hay from each experimental plot were used to calculate the dry matter and to determine the total N using the Kjeldahl method and subsequently the total protein content. In most cases differences were found between the treatments concerning the dry matter and the protein content giving a better proportion in the mixtures.

Key words: *intercropping, dry matter, protein content.*

INTRODUCTION

Legumes are very important crops in Greece, because both hay (dry grass) and seed are considered to be high-nutrient feed, due to their high protein content (30-35%), inorganic minerals calcium and phosphorus and vitamins. In addition, legume proteins are characterized as proteins of high biological value, which makes them an essential component of animal feed, as a supplement to cereals. Intercropping of most annual legumes with winter cereals is a very common practice for animal feed production in many countries (Qamar et al., 1999; Clergue et al., 2005). One of the

most widely used legumes in intercropping systems in the Mediterranean region is common vetch (*Vicia sativa L.),* an annual plant that contains high levels of protein and is grown with cereals to produce hay or seed. Another livestock feed that could also be used in mixtures is faba beans (*Vicia faba L.*), an annual well-adapted legume in Greece, due to the high content of their seed in protein (26.5%). According to research data, intercropping of legumes with cereals provides stable biomass yields and forage quality, (Lithourgidis et al., 2007; Galanopoulou et al., 2019) and has a positive effect to soil properties, to efficient competition with weeds, and extension of harvest time (Banik et al. 2006,Vasilakoglou et al. 2008). There are also some, biological and ecological advantages in intercropping over mono-cropping (Mohammed et al., 2008, Jensen et al. 2020). However, it has been found that the competition of cultivated plants in water, nutrients and light usually reduces the yield of the mixture compared to monoculture (Lithourgidis et al., 2008, Lithourgidis and Dordas 2010, Menber et al., 2015). So, mush careful considerations are needed in order to select the proper intercropping system. The objective of this study was to determine the effect of intercropping cereals with forage legumes on silage yield and protein content under the special climatic conditions of the Florina area.

MATERIALS AND METHODS

In the farm of the University of Western Macedonia in Florina, the cultivation season 2019-2020, Greek varieties of livestock legumes and cereals were intercropped. Particularly, common vetch, forage pea and faba beans were used as forage legumes, and barley, bread wheat and triticale were used as cereals, which were grown individually as well as intercropped with each other in mixed rows in a sowing ratio 65:35.Thus 15 different treatments were created and a total of 45 experimental plots was installed. The examined genotypes were sown in early November 2019 in a field, that had been cultivated with cereals the previous season, in a sandy loam soil. The plots consisted of seven rows five meters long of which the five inner were harvested. The distances between rows were 0.25m. The completely randomized design with three replications was used. The field was fertilized only with diammonium phosphate (20-10-0) before sowing so that 80 and 40 kg ha^{-1}, Nitrogen and P_20_5 respectively were added into the soil. The crop was kept free of weeds by hand hoeing when necessary. The total chloromass was harvested around the end of the legume flowering period (late May - early June) and dried naturally to form hay. The plants were separated by hand to determine the fresh weight of each species. Samples of 100 g of hay from each experimental plot were placed at 65oC for 96h to calculate the dry matter, and in addition to determine the total N using the Kjeldahl method and subsequently the total protein content. Data were statistically analyzed and the means were compared according to LSD test at p=0.05.

RESULTS AND DISCUSSION

Significant differences were recorded between the examined cultivars in fresh and dry weight (significant differences at p=5%, Table 1). Fresh weight ranged from 35940Kg/ha in mixture bread wheat+ forage pea to 11660 kg/ha in faba bean (monocropping) (Table 1).The mixtures triticale + forage pea and barley +forage pea and the monocropping forage pea showed high yield as well. Dry weight ranged from 12240Kg/ha in mixture bread wheat+ forage pea to 3120 kg/ha in faba bean (monocropping). So concerning the dry matter the mixture bread wheat+ forage pea is still more productive. The superiority of wheat as the cereal included in an intercropping system was stated also by Roberts et al. (1989). Nevertheless in this study the mixtures barley + vetch, barley + forage pea, triticale + vetch and triticale + forage pea had almost equally high yield as well. The above results suggest that the intercrops may have higher dry matter yield than the respective monocrops. The same was reported by Chapagain and Riseman, (2014) when barley is intercropped with pea in a sowing ratio 2:1. Nevertheless Javanmard et al. (2014) reported that the intercropping of barley with vetch and grass pea, resulted in reduced dry matter yield compared to their respective monocrops.

Table 1. The fresh weight, the weight of dry matter, the protein content % fresh weight, and the protein content % dry weight

GENOTYPE	Fresh Weight Kg/ha	Dry Weight Kg/ha	Protein % fresh weight	Protein % dry weight
Triticale	15340e	7380b	2.91gh	6.26g
Bread wheat	14340e	7980b	2.56h	4.87g
Barley	12660e	7660b	3.97efgh	6.43g
Forage Pea	28400abc	7840b	6abcd	20.18a
Vetch	17660de	6780bc	7ab	17.98abc
Faba beans	11660e	3120c	5.62abcde	19.85ab
Triticale + Forage Pea	29140ab	8600ab	5.26bcde	11.77def
Triticale+ Vetch	23540bcd	9840ab	6.53abc	14.84bcd
Triticale + Faba beans	20340cde	7920b	4.67defg	10.78def
Bread wheat + Forage Pea	35940a	12240a	4.23defgh	11.13def
Bread wheat + Vetch	20460bcde	8240b	4.78cdef	12.21de
Bread wheat + Faba beans	15660de	6500 bc	3.09fgh	7.84fg
Barley + Forage Pea	27600abc	8920ab	5.47abcde	14.02cd
Barley + Vetch	20260cde	9920ab	7.26a	14.14cd
Barley+ Faba beans	15540e	7900b	3.96efgh	8.68efg

Means in columns followed by different letters, are significantly different at $p<0.05$ by LSD test.

Regarding the protein content % fresh weight and protein content % dry weight, the differences were significant (Table 1). The protein content % fresh weight ranged from 7.26% in mixture barley + vetch to 2.56 in bread wheat. The protein content % dry weight ranged from 20.18% in forage pea to 4.87 in bread wheat. Faba beans and vetch did not differ significantly from the forage pea concerning the protein content % dry weight. The mixture triticale+vetch was the best among the mixtures following by the barley +forage pea and barley+vetch and all of them were significantly better than the cereals monocrops. The same was reported by Lauk and Lauk (2005) who concluded higher protein yield in intercropping legumes with cereals compared to respective monocrop of cereal. Lithourgidis et al. (2007) reported that intercropping common vetch with barley or winter wheat produced forage of higher quality than the other intercrops. In this study this is not entirely the case because the mixture wheat +vetch showed intermediate protein content % dry weight. Additionally, it should be mentioned that the most productive mixture bread wheat+ forage pea had intermediate protein content % dry weight and the mixtures that combine both high yield and high protein content are the triticale+ vetch and the barley intercropping with forage pea and vetch.

CONCLUSIONS

It was concluded that concerning the dry matter the mixture bread wheat + forage pea is more productive followed by the mixtures of barley and triticale intercropped with common vetch, and forage pea. Forage pea, faba beans and common vetch have higher protein content % dry matter compared to other monocrops and the mixtures. Among the mixtures the triticale + vetch and the intercrop of barley with forage pea and common vetch had higher protein content % dry matter and therefore were the ones that could produce forage of high quality. A first estimate of these results leads to the conclusion that promising mixtures for production of high quality forage are the mixture triticale + common vetch and the intercrop of barley with forage pea and common vetch. However, further research, including several seeding ratio and different spatial arrangement of the individual crops, is needed to confirm the results of the present study.

ACKNOWLEDGEMENTS

Financial support of this project (project code 70313) by the Special Account for Research Grants of University of Western Macedonia, Greece, is gratefully acknowledged**.**

REFERENCES

Banik P, Midya A, Sarkar B, Ghose S (2006). Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering Eur. J.Agron. 24 pp. 325-332

ChapagainT., Riseman A. (2014). Barley-pea intercropping: Effects on land productivity, carbon and nitrogen transformations. Field Crops Research. 166 pp.18-25.

Clergue B., Amiaud B., Pervanchon F., Lasserre-Joulin F., Plantureux S. (2005). Biodiversity: function and assessment in agricultural areas, A review. Agron. Sustain. Dev. 25 pp. 1–15.

Galanopoulou K., LithourgidisA.,Dordas C. (2019). Intercropping of Faba Bean with Barley at Various Spatial Arrangements Affects Dry Matter and N Yield, Nitrogen Nutrition Index, and Interspecific Competition / Not Bot HortiAgrobo, 47(4) pp.1116-1127

Javanmard A., Nasiri Y., Shekari F. (2014).Competition and dry matter yield in intercrops of barley and legume for forage. Albanian J. Agric. Sci. 13pp.22-32

Jensen E.S., Carlsson G., Hauggaard-Nielsen H. (2020).Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis Agronomy for Sustainable Development. 40 pp.5

Lauk, R., Lauk, E. (2005) The yields of legume-cereal mixes in years with high-precipitation vegetation periods.Latvian Journal of Agronomy. 8 pp.281–285.

Lithourgidis A.S.,Dordas C.A. (2010). Forage yield, growth rate, and nitrogen uptake of faba bean intercrops with wheat, barley, and rye in three seeding ratios. Crop Science. 50 pp. 2148-2158.

Lithourgidis, A.S., C.A., Dordas, T.B., Lazaridou, I., Papadopoulos, 2008. Silage yield and protein content of common bean intercropped with corn in two row-replacements. Proceedings of 10th Congress of the European Society for Agronomy, 15-19 September 2008, Bologna, Italy.

Lithourgidis A.S., Dhima K.V., Vasilakoglou I.B., Dordas C.A., Yiakoulaki M.D. (2007). Sustainable production of barley and wheat by intercropping common vetch. Agronomy for Sustainable Development, 27 (2) pp. 95

Menber S., Dejene M., Abreha S. (2015). Dry matter yield and agronomic performance of herbaceous legumes intercropped with napier grass (*Pennisetumpurpureum*)in the semi-arid areas of eastern amhara region. International Journal of recent research in life sciences 2 (1) pp. 7-14.

Mohammed I.B., Olufajo O.O, Singh B.B., Miko S., Mohammed S.G. (2008). Evaluation of yield of components of sorghum/cowpea intercrops in the Sudan savanna ecological zone. ARPN J. Agric. Biol. Sci. 3 pp. 30-37

Qamar I.A., Keatinge J.D.H., Mohammad N., Ali A., Khan M.A. (1999). Introduction and management of common vetch/barley forage mixtures in the rainfed areas of Pakistan. 3. Residual effects on following cereal crops, Aust. J. Agr. Res. 50 pp. 21–27.

Roberts C.A., Moore K.J., Johnson K.D. (1989). Forage quality and yield of wheat-vetch at different stages of maturity and vetch seeding rate. Agron J 81pp. 57-60.

Vasilakoglou I.,Dhima K., LithourgidisA., Eleftherohorinos I. (2008). Competitive ability of winter cereal-common vetch intercrops against sterile oat. Experimental Agriculture, 44 pp. 509-520.

Original Scientific paper
10.7251/AGRENG2002077P
UDC 551.557.38:633.15]:577.2

THE ESTIMATION OF HEAT AND DROUGHT TOLERANCE MAIZE LINES USING DNA MARKERS

Larysa PRYSIAZHNIUK[1*], Yurii HONCHAROV[2], Yuliia SHYTIKOVA[1], Snizhana CHERNII[1], Viktoria HURSKA[1], Svitlana TKACHYK[1]

[1]Ukrainian Institute for Plant Variety Examination, Ukraine
[2]Research Institute of Agrarian Business, Ukraine
*Corresponding author: prysiazhniuk_l@ukr.net

ABSTRACT

The main factor which causes to decrease maize grain yield is drought. In most regions where maize is grown, the water stress during the growing period is caused by both lack of soil moisture and high air temperature. The purposes of our study were the estimation and selection of maize lines for drought and heat tolerance based on DNA markers and determination of the correlation between CAPS markers and plant ability to resist the water stress. As the result of study, the significant differences were found between leaf temperature of maize lines which contained favorable alleles by both CAPS markers in 2018 and 2019 (35.72 and 34.41ºC respectively), $LSD_{0.05}$=1.27. The leaf temperature of maize lines which had SNP (A) by dhn C397 (36.95ºC) differenced significantly with lines contained favorable allele by rspC1090 or lines with no favorable alleles in 2018 (33.68 and 34.35ºC respectively). Based on analysis by seeds germinating in sucrose solution the significant differences were observed between the amount of sprouted seeds in lines contained SNP(G) by rspC1090 and lines without any favorable allele (4% and 2.25% respectively), $LSD_{0.05}$= 1.70. As the result of correlation analysis, the positive correlation was determined between SNP(A) by dhnC397 marker in maize lines and leaf temperature in 2018-2019 (r=0.16). The positive correlation was observed between SNP(G)byrspC1090 and the percent of sprouted seeds in sucrose solution (r=0.31). Thus, for complex estimation and maize line selection for drought and heat tolerance it could be recommended to use two CAPS markers dhnC397 and rspC1090.

Keywords: *drought, high temperature, CAPS markers, correlation, maize.*

INTRODUCTION

The maize figures prominently among cereal crops. The need to grow this crop in drought regions is determined by its high productivity in comparison with other crops, as well as a wide range of uses (Panfilova *et al.*, 2020). Therefore, for current breeding, great importance is given to the creation of breeding material and its selection for new maize hybrids. The one of the main stress factors which limits

maize yield is drought. In most regions where maize is grown, water stress during the growing season occurs unpredictably. Soil drought is caused by a prolonged absence of rain combined with high air temperature and solar insolation, increased water evaporation from the soil and plants dehydration through transpiration. Atmospheric drought is characterized by high temperature and relatively low humidity (10-20%). Significant atmospheric drought occurs due to the movement of air currents – hot dry winds. It contributes to the disruption of the dynamics of the water flow from the soil into the above-ground organs of plant and its loss by the plant by dramatically increasing the water evaporation from the soil and transpiration (Prodan and Zatula, 2009). Usually, atmospheric and soil droughts occur at the same time. The atmospheric droughts itself often arises in the spring, when the soil is still saturated with water after the snow melts. Soil drought is often observed in the middle or end of summer, when winter water reserves have already been used, and summer precipitation was insufficient.

The selection of drought tolerant maize breeding materials is carried out mainly based on the assessment of yield, changes in the physiological state of plants, assessment of the state of vegetative and generative organs of the plant in the field (Chen *et al.*, 2012; Massino *et al.*, 2013; Krivosheev *et al.*, 2016; Maazou *et al.*, 2016; Satarova *et al.*, 2016; Effendi *et al.*, 2019). The possibilities of molecular biology and plant genetics allow the use of knowledge about the structure of the genome and the genes expression to select drought-tolerant maize lines. Based on Hao *et al.* (2011) studies Liu *et al.* (2015) developed two functional CAPS (Cleaved Amplified Polymorphic Sequences) markers to identify allelic states of *dhn1* and *rsp41* genes associated with drought resistance of maize. In our previous studies (Prysiazhniuk *et al.*, 2018), the assay maize lines by DNA markers to *dhn1* and *rsp41* genes was carried out and it was identified lines with various combinations of favorable alleles. To assess the efficiency of DNA markers selection Hao *et al.* (2011a) proposed criteria for selecting drought tolerant lines based on six indicators: yield, ears per plant, kernel number per row, plant height, anthesis–silking interval, leaf curling.

However, despite the fact that the positive correlation between drought tolerance and the seeds ability to germinate in osmotic solutions (sucrose, mannitol, sorbitol, etc.) has been known, it is interested to determine the efficiency of the maize lines selection by DNA markers and the rapid assessment of drought resistance by germination ability seeds in osmotic solutions. Also, there are studies which confirm that the determination of leaf surface temperature is used for a quick assessment of the plant water status. The water deficit affects leaf temperature by gradually decreasing transpiration as a result of stomata closure (Kögler and Söffker, 2019). Hence, decreased transpiration leads to an increase a leaf temperature. It has been proven that there is a linear correlation between leaf temperature and transpiration (Liu *et al.*, 2011). Therefore, to evaluate maize lines in which favorable alleles were identified by CAPS markers, it is relevant to determine their ability to resist drought and heat using alternative methods for assessing plant response to water stress. The purpose of the study is to evaluate and

select drought and heat tolerance maize lines based on DNA markers and to determine the correlation between CAPS markers and the ability of maize plant to resist to water stress.

MATERIAL AND METHODS

Plant material and DNA analysis

In this study 74 inbred maize lines which had been tested the presence favorable alleles by CAPS markers dhnC397 and rspC1090 to genes *dhn1* and *rsp41* respectively were investigated.

DNA extraction, PCR condition, digestion by restriction enzymes and products separation are described in our previous studies (Prysiazhniuk *et al.*, 2018).

Laboratorial experiment

The laboratorial experiment for determination of the maize seeds ability to germinate in osmotic solution was conducted in Laboratory Molecular Genetic Analysis of Ukrainian Institute for Plant Variety Examination (Kyiv, Ukraine) in 2018. For estimation maize inbred lines, the sucrose solution was used with osmotic pressure 10-12 atm (Oleynikova and Osipov, 1976). According to the van't Hoff equation, the concentration of sucrose solution is 0.5 M. It was sown 300 seeds of studied lines and 200 seeds as control (50 seeds to each Petri dish). The 5 ml of osmotic solution was added to each Petri dish for studied lines and 5 ml of water for control. Petri dishes with seeds were incubated in thermostat at 25ºC during 5 days. Then, counting percent of the germinated seed (G) was carried out: the ratio of the average number of germinated seeds in sucrose solution (Awg) to the average number of germinated seeds in the control (N):

$G = Awg/N \times 100\%$.

Field experiment

The field experiment was carried out during 2018-2019 at the experimental sites of Research Institute of Agrarian Business (Dnipro, Ukraine). The temperature of 6-7th leaf of maize lines was measured at the growth stage of development of fruit which came at the first decade of August. It was assayed 21 maize plant of each line with infrared pyrometer Benetech GM550 (China), sensitivity is 0.1ºC. The leaf temperature was measured at the hottest period of day between 1.30 pm and 2.30 pm (Liu *et al.*, 2011; Kögler and Söffker, 2019). For addition estimation of heat and drought tolerance of maize lines which had the different combination of alleles, the yield of studied lines was assayed.

Weather conditions

The weather conditions rates of Research Institute of Agrarian Business in Vesele village (Sinelnykove district, Dnipro region) were provided by Sinelnykove weather station. The air temperature and amounts of precipitation during maize growing cycle in 2018-2019 are shown in Table 1.

Table 1. The air temperature and amounts of precipitation during 2018-2019 maize growing cycle.

Month	Air temperature, ºC			Amounts of precipitation, mm		
	Daily average air temperature	2018	2019	Daily average amounts of precipitation	2018	2019
April	9.2	12.9	10.9	35.0	20.1	14.1
May	15.8	18.6	18.1	50.0	37.0	21.3
June	19.1	21.4	23.9	59.0	43.5	1.0
July	20.9	22.7	20.9	61.0	69.5	33.7
August	20.1	23.6	20.9	35.0	0.0	73.4
September	15.0	18.4	16.1	36.0	23.0	6.4

Statistical analysis

The deviation coefficient of agrometeorological indicators from daily average amounts during studied years was computed using the equation below:

$$Dc = \frac{(X_i - \bar{X})}{\sigma}$$

where *Dc* – deviation coefficient; *Xi* – indicator of current weather; *X* – daily average amounts; σ – mean-square deviation.

The rate of deviation coefficients was determined according to scale: *Dc* =0-1 – close to normal conditions; *Dc* =1-2 – strong different conditions; *Dc* > 2 – close to unique conditions (Yeremenko *et al*., 2017).

To determine the significant differences of studied indicators the ANOVA is used. The correlation is computed by Spearmen correlation coefficients analysis

RESULTS AND DISCUSSION

As results of inbred maize lines studies by CAPS markers the polymorphism, which indicates drought tolerance and susceptible lines, was determined. According to Liu *et al.* (2015) the polymorphism of CCAAAG(A) type by dhnC397 marker which is associated with drought tolerance is detected by presence only one amplicon of size 164 bp. Two amplicons of size 225 and 61 bp are identified in drought tolerant lines carrying CCGG(G) polymorphism by rspC1090 marker (Liu *et al*., 2015; Prysiazhniuk *et al.*, 2018) (Fig. 1, 2).

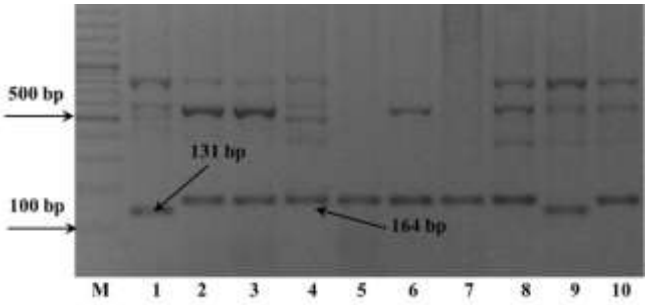

Fig. 1. Electrophoresis of PCR and restriction analysis products (marker dhnC397): 1- RAM 70; 2 – RAM 71; 3 – RAM 73; 4 – RAM 74; 5 – RAM 77; 6 – RAM 86; 7 – RAM 87; 8 – RAM 88; 9 – RAM 89; 10 – RAM 90; M − marker of molecular weight Thermo Scientific O'RangeRuler 100 bp DNA Ladder.

As result of PCR analysis by dhnC397 marker and digestion by StyI restriction enzyme the amplicons of expected size were detected at the electropherogram. The amplicons 164 bp were detected in lines carrying SNP CCAAAG(A) and they are drought tolerant. The polymorphism CCAAAG(G), which is identified by dhnC397 marker in drought susceptible lines, is detected by presence two amplicons of size 131 and 33 bp. In total, of the 74 studied lines, favorable alleles by dhnC397 marker were found in 50 lines, which accounts 68% of the total number of lines.

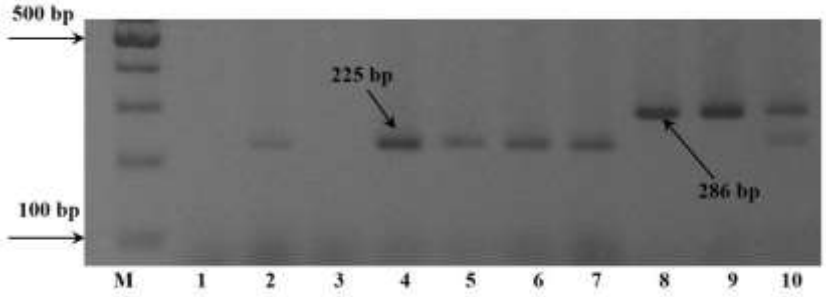

Fig. 2. Electrophoresis of PCR and restriction analysis products (marker rspC1090): 1- RAM 54; 2 – RAM 55; 3 – RAM 56; 4 – RAM 57; 5 – RAM 59; 6 – RAM 60; 7 – RAM 61; 8 – RAM 63; 9 – RAM 64; 10 – RAM 65; M − marker of molecular weight Thermo Scientific O'Range Ruler 100 bp DNA Ladder.

SNP CCGG(G) which is detected by rspC1090 marker and HpaII restriction enzyme was identified in 25 lines (34% of the total number of lines). As result of electrophoresis of PCR and restriction analysis products it was determined two amplicons of size 225 and 61 bp. The maize lines, which the amplicon 286 bp was found in, have the polymorphism CCGG(A). They are susceptible to drought.
Therefore, favorable alleles associated with drought in maize were detected in 14 studied lines by both markers dhnC397 and rspC1090 which accounts 5% of the total number of lines. The amount of lines which had the favorable allele only by

dhnC397 marker was 36 (49%); there were 11 lines (15%) which the favorable allele was identified in by rspC1090 marker. No alleles were detected in 13 studied maize lines. Liu *et al.* (2015) studied 210 Chinese maize lines which had a different rates of drought tolerance. As results of their researches, it was determined that 141 lines had favorable alleles by dhnC397 marker and 109 maize lines – by rspC1090 marker.

According to these results the possibility of using dhnC397 and rspC1090 markers as functional markers for lines selection in breeding programs of drought tolerance was proved. For Ukrainian maize lines in our studies the percent of favorable alleles were fewer. However, Liu *et al*. (2015) note that they have already estimated 201 maize lines by morphological characteristics and yield indicators in field. In our experiment the preliminary assessment of maize lines by CAPS markers was conducted, and then its efficiency was verified by alternative approaches using seed germination in sucrose solution and by measuring the leaf surface temperature.In order to assess the ability of maize lines to heat tolerance in field condition the leaf temperature was measured and lines were compared according to presence the favorable alleles by studied CAPS markers.

In accordance with obtained data the average leaf surface temperature of maize lines, which had the favorable alleles by both markers in 2018 was 35.72ºC, in 2019 - 34.41ºC. The average leaf surface temperature of maize lines, which had the favorable alleles by dhnC397 marker was 36.95ºC in 2018 and 35.63ºC in 2019. It was found that in lines carrying the favorable alleles by rspC1090 marker the temperature was 33.68 and 35.30ºC in 2018 and 2019 respectively. The leaf surface temperature of maize lines which had no favorable alleles by studied markers was 34.35 and 34.75ºC in 2018 and 2019 respectively (Fig. 3).

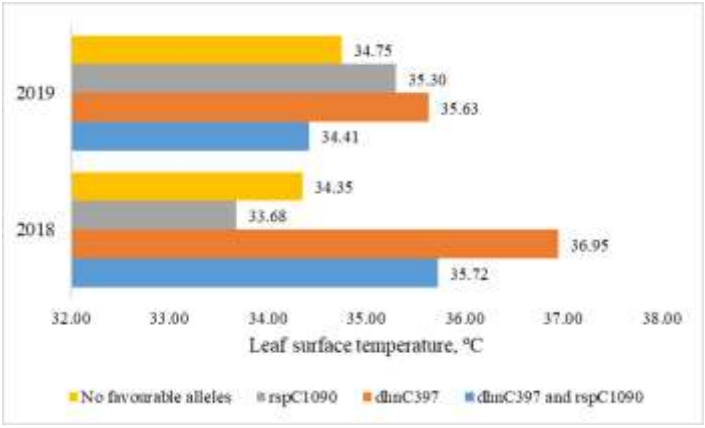

Fig. 3. The average leaf surface temperature of maize inbred lines in 2018 and 2019 ($LSD_{0.05}$=1.27)

As results of studies it was determined the significant differences between average leaf surface temperature of maize lines carrying the favorable alleles by dhnC397 and rspC1090 in 2018. Furthermore, the significant differences were observed between average leaf surface temperature of maize lines with favorable alleles by dhnC397 marker depending on years of experiment. There were not the significant differences between maize lines carrying the favorable alleles by rspC1090 marker and lines with no favorable alleles. It should be noted that average leaf surface temperature of maize lines with favorable alleles by both markers (35.72ºC) and lines carrying the favorable alleles by dhnC397 marker (36.95ºC) in 2018 differ significantly from maize lines with no favorable alleles (34.35ºC) and lines with presence favorable alleles by rspC1090 marker (33.68ºC). There were not any significant differences between the leaf surface temperature of maize lines in 2019.

The significant differences in the leaf surface temperature of maize lines that was observed in 2018 can be explained by a significant variation in air temperature depending on years of research. According to the calculated deviation coefficient by months, it was determined that at the growth stage of development of fruit (August), *Dc* for air temperature is 2 in 2018 and 0 in 2019. This indicates that the air temperature in 2018 was significantly higher than the daily average air temperature during this growing cycle. It was determined that drought tolerance maize lines carrying favorable alleles by both dhnC397 and rspC1090 markers, and only by dhnC397 marker reduced the transpiration. It occurred as response to high air temperature due to that water loss was reduced and reduced transpiration led to an increase the leaf surface temperature of maize lines.

The deviation coefficient for amounts of precipitation in August 2018 and 2019 was -1 and 1 respectively that indicates the weather condition as close to normal conditions. However, the amount of precipitation in 2019, from April to June, was significantly lower compared to the normal amount (*Dc*=-2), which indicates a water deficit in the soil during these growing cycles. Therefore, the determination of the maize lines' ability to germinate in osmotic solutions can be informative for assessing the studied lines in water lack of soil.

To determine the drought tolerance of maize lines by germinating seeds in a sucrose solution, lines with a different combination of favorable alleles were selected according to functional drought tolerance markers: 5 lines with favorable alleles by both markers, 7 lines with favorable alleles by dhnC397 marker, 5 lines with favorable alleles by rspC1090 marker and 3 lines with no favorable alleles.

As a result of the studies, it was determined that the number of seeds that were able to sprout in a sucrose solution ranged from 0 to 7.33%. The average number of seeds for genotypes carrying both favorable SNP(A)(G) is 2.54%, lines with SNP(A) by dhnC397 marker - 2.46%, lines with SNP(G) by rspC1090 marker - 4%, for genotypes with no favorable alleles - 2.25% ($LSD_{0.05}$=1.70). According to ANOVA results, it was found that the percentage of germinated seeds in sucrose solution did not differ significantly depending on the combination of favorable alleles. However, significant differences were found between the number of seeds

capable of germination in sucrose solution in lines carrying a single favorable allele and lines that had SNP(G) by rspC1090 marker.

Studies conducted by Rotari *et al.* (2018), found a wide range of variation of the resistance coefficient to seeds physiological dryness on sucrose solution - from 0.00 to 1.05%. Based on the study of indicators complex of the leaf water regime and the developed scale for assessing drought tolerance, the authors proved the effectiveness of seed germination on an osmotic solution for early detection of maize drought-resistant forms (Rotari *et al.*, 2018). The water stress using sorbitol was simulated also in the work of Valentovic *et al.* (2006). The authors evaluated the effect of water deficiency on the antioxidant enzymes activity in two maize hybrids. Based on their data, a significant effect of water stress on 13-day old seedlings of the studied varieties was determined (Valentovic *et al.*, 2006). This confirms the presence of various mechanisms to resist an atmospheric and soil drought.

To determine the correlation between the presence of favorable alleles by CAPS markers and the ability of the studied maize lines to resist high air temperatures and water stress, a Spearmen correlation coefficients analysis was computed. As a result of calculations, the presence of a positive correlation between the presence of favorable allele by dhnC397 marker in maize lines and leaf surface temperature in 2018-2019 was determined (r=0.16). A negative correlation was found between the presence of a favorable allele by rspC1090 marker and leaf surface temperature in 2018-2019 (r=-0.20).

According to the assessment of correlation between the presence of favorable alleles by CAPS markers and the ability of the studied lines to germinate under the osmotic stress on a sucrose solution, a positive correlation was found between the presence of a favorable allele by rspC1090 marker and the percentage of germinated seeds of maize lines (r=0.31). However, a negative correlation was found between the percentage of germinated seeds on a sucrose solution and the presence of a favorable allele by dhnC397 marker (r=-0.32).

Liu *et al.* (2011) studied 187 recombinant maize lines using infrared thermography and evaluated the plants response to water stress. The authors also conducted studies of the correlation between the difference of leaf temperature and shoot biomass. As a result of studies, the authors noted a significant increase of the leaf temperature of the studied lines under water stress. The results obtained by Liu *et al.* (2011) indicate that there is a positive correlation between the difference of leaf temperature and shoot fresh weight and shoot dry weight, the correlation coefficients were 0.160 and 0.163, respectively (Liu *et al*., 2011).

In our studies, despite some differences in the experiment organization, significant differences were also found between the leaf temperature in drought. However, according to the purpose of our studies, a positive correlation was found between the presence of a favorable allele by dhnC397 marker in maize lines over the studied years and the leaf surface temperature. Significant differences in leaf temperature in maize hybrids due to atmospheric drought were discovered by Coskun *et al.* (2011). The authors investigated the physiological parameters of

maize hybrids under high air temperatures in the field. A positive correlation was determined between the leaf temperature and days to flowering, relative injury and chlorophyll content *b* (*Chla/b*) (Coskun *et al.*, 2011).

Kögler and Söffker (2019) studied the features of explorative frequency analysis for measuring the leaf temperature of maize under water stress. The authors conducted an experiment in controlled laboratory conditions studying the leaf temperature under water deficit of the substrate using infrared camera. As a result of the analysis, the authors did not find any correlation between the leaf temperature and water deficit (Kögler and Söffker, 2019). According to our results, a negative correlation was found between ability to germinate under osmotic stress in lines carrying the favorable allele by rspC1090 marker and the leaf surface temperature of studied maize lines. However, a positive correlation was noted between the presence of a favorable allele by rspC1090 marker and the number of germinated seeds in a sucrose solution. Thus, our studies also confirm that the change of leaf temperature of maize does not depend on water deficit in the soil or substrate, but there are significant differences under atmospheric drought.

The *dhn1* gene is known to encode dehydrin, which protects plant vegetative tissue cells from dehydration (Rorat, 2006). Thus, it can be assumed that the presence of the favorable allele of the *dhn1* gene indicates the ability of the maize lines carrying this allele to resist atmospheric drought. Consequently, maize lines with the favorable allele by dhnC397 marker are perspective for producing heat tolerant maize hybrids.

The *rsp41* gene encodes an arginine/serine-rich splicing factor. According to Palusa *et al*. (2007) the strong influence of heat and cold and some hormones on alternative splicing of specific serine/arginine-rich genes suggests that some of the dynamic changes in plant transcriptome in response to abiotic stress can be caused by changes in the serine/arginine-rich proteins structures and their isoforms. In addition, serine/arginine-rich genes that express altered splicing variants in response to stress provide a unique opportunity to use them as a model to analyze the mechanisms by which stress signals modulate alternative splicing and plants respond to water deficit. Thus, the use of rspC1090 marker to the *rsp41* gene can be considered as a means for identifying genotypes that are resistant to water deficit in soil.

The significant differences were noted between lines carrying favorable alleles by both dhnC397 and rspC1090 markers and lines with no favorable alleles by yield of studied lines (Fig. 4). According to obtained data, it was determined that the average yield of maize lines that had favorable alleles by both CAPS markers was 2.70 and 2.50 t ha^{-1} in 2019 and 2018, respectively. The yield of lines carrying favorable alleles by one of the studied markers was 2.10-2.24 t ha^{-1} in 2018 and 2.20-2.31 t ha^{-1} in 2019. The diagram shows that there were no significant differences in yield of studied lines between the years, and also in accordance with the presence of favorable alleles.

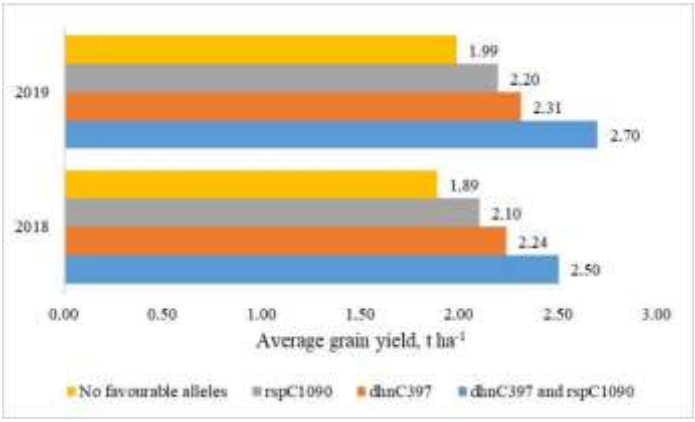

Fig. 4. The average grain yield of maize inbred lines in 2018 and 2019 ($LSD_{0.05}$=0.59)

The grain yield did not differ significantly depending on the years. However, in 2019, a slightly higher yield was observed for all studied lines. This can be explained by the fact that, in accordance with the amount of precipitation and air temperature, 2018 was a more arid during maize growing cycle. Based on climate change analysis and maize yield it was determined that an increase the average air temperature by 1, 2 and 4°C relative to the baseline climate resulted in a yield reduction of 1-21%, 3-34% and 17-67%, respectively (Tesfaye *et al.*, 2018). Authors shown that varieties with combined heat and drought tolerance traits increased maize yield by 3-150%, 4-185% and 7-329% under the hotter and drier climate change scenarios with the average temperature increase of 1, 2, and 4°C, respectively. Therefore, lines, which showed tolerance to heat and drought by studied CAPS markers, can be perspective not only for obtaining resistant hybrids to adverse environmental conditions, but also for obtaining a stable yield under water deficit.

Cairns *et al.* (2013) investigated inbred maize lines ability to resist heat and drought in various arid regions in the field. The authors determined that genetic control of drought and heat tolerance are largely independent of each other (Cairns *et al.*, 2013). Their results are confirmed by our studies very clearly, since the revealed correlations between leaf surface temperature and the presence of a favorable allele by dhnC397 marker associated with the gene encoding dehydrin, as well as a positive correlation between the presence of a favorable allele by rspC1090 marker and the percentage of germinated seeds in osmotic solution indicate different mechanisms for regulating heat resistance and water deficit in soil.

Scientists (Cairns *et al.*, 2013) also noted a significant yield loss of the studied maize lines under the heat. In our studies in 2018, which was characterized by a high air temperature, the yield of the studied maize lines was lower and significantly differed in lines that turned out to be susceptible to heat and drought by both studied CAPS markers.

Chen *et al.* (2012) investigated the effects of heat and soil drought to inbred maize lines in the field based on estimates of plant height, relative water content, leaf firing, leaf blotching, and tassel blasting. According to the results, drought and heat resistant genotypes were selected by authors. Also, the authors proved the inheritance of heat tolerance by hybrids. Therefore, the heat and drought tolerance lines selected as results of our studies can be used in future breeding programs to obtain hybrids resistant to heat and drought. Thus, according to obtained results, dhnC397 and rspC1090 markers can be recommended for selection of maize breeding material of heat and drought tolerance.

CONCLUSIONS

As a result of studies of 74 inbred maize lines using two CAPS markers, it was determined that favorable alleles were identified by both dhnC397 and rspC1090 markers in 14 maize lines, in 36 lines - by dhnC397 marker and in 11 - with rspC1090 marker. The significant differences between leaf surface temperature depending on the year were determined in lines with favorable allele by the dhnC397 marker. As a result of analysis maize lines ability to germinate in the osmotic solution, significant differences were found between the number of germinated seeds in lines with no favorable alleles and lines that had a favorable allele by the rspC1090 marker.

According to the results of the correlation analysis, a positive correlation was determined between the presence of a favorable allele by dhnC397 marker in maize lines and leaf surface temperature in 2018-2019 (r=0.16), a positive correlation was also found between the presence of a favorable allele by rspC1090 marker and the percentage of germinated seeds of maize lines in sucrose solution (r=0.31). Thus, for a comprehensive assessment and selection of maize lines to heat and drought tolerance, the using of two CAPS markers dhnC397 and rspC1090 can be recommended.

REFERENCES

Cairns, J. E., Crossa, J., Zaidi, P. H., Grudloyma, P., Sanchez, C., Araus, J. L., ... & Menkir, A. (2013). Identification of drought, heat, and combined drought and heat tolerant donors in maize. *Crop Science*, *53*(4), 1335-1346. https://doi.org/10.2135/cropsci2012.09.0545

Chen, J., Xu, W., Velten, J., Xin, Z., & Stout, J. (2012). Characterization of maize inbred lines for drought and heat tolerance. *Journal of soil and water conservation*, *67*(5), 354-364. https://doi.org/10.2489/jswc.67.5.354

Coskun, Y., Coskun, A., Demirel, U., & Ozden, M. (2011). Physiological response of maize ('Zea mays'l.) to high temperature stress. *Australian Journal of Crop Science*, *5*(8), 966. https://doi.org/10.1007/s12374-018-0350-x

Effendi, R., Priyanto, S. B., Aqil, M., & Azrai, M. (2019, May). Drought adaptation level of maize genotypes based on leaf rolling, temperature, relative moisture content, and grain yield parameters. In *IOP Conference Series: Earth*

and Environmental Science (Vol. 270, No. 1, p. 012016). IOP Publishing. https://doi.org/10.1088/1755-1315/270/1/012016

Goncharova, E. A., Chesnokov, Yu. V., & Sitnikov, M. N. (2013). Retrospect of researches of a water status cultural plants on the basis of collection Vavilov All-Russian Research Institute of Plant Industry genetic resources. *Transactions of the Karelian Research Centre of the Russian Academy of Sciences*, (3), 10-17. [in Russian]

Hao, Z. F., Li, X. H., Su, Z. J., Xie, C. X., Li, M. S., Liang, X. L., ... & Zhang, S. H. (2011a). A proposed selection criterion for drought resistance across multiple environments in maize. *Breeding science*, *61*(2), 101-108. https://doi.org/10.1270/jsbbs.61.101

Hao, Z., Li, X., Xie, C., Weng, J., Li, M., Zhang, D., ... & Zhang, S. (2011b). Identification of functional genetic variations underlying drought tolerance in maize using SNP markers. *Journal of integrative plant biology*, *53*(8), 641-652. https://doi.org/10.1111/j.1744-7909.2011.01051.x

Kögler, F., & Söffker, D. (2019). Explorative Frequency Analysis of Leaf Temperature Behavior of Maize (Zea mays subsp. mays) at Water Deficit. *Plants*, *8*(4), 105. https://doi.org/10.3390/plants8040105

Krivosheev G. Y., Shevchenko N. A., Gaze V. L., & Anisimova N. N. (2016). The initial material for breeding of drought tolerant hybrids of maize. *Agrarian Science of Euro-North-East*, *6*(55), 15-19. [in Russian]

Liu, S., Hao, Z., Weng, J., Li, M., Zhang, D., Pan, G., ... & Li, X. (2015). Identification of two functional markers associated with drought resistance in maize. *Molecular breeding*, *35*(1), 53. https://doi.org/10.1007/s11032-015-0231-7

Liu, Y., Subhash, C., Yan, J., Song, C., Zhao, J., & Li, J. (2011). Maize leaf temperature responses to drought: Thermal imaging and quantitative trait loci (QTL) mapping. *Environmental and Experimental Botany*, *71*(2), 158-165. https://doi.org/10.1016/j.envexpbot.2010.11.010

Maazou, A. R. S., Tu, J., Qiu, J., & Liu, Z. (2016). Breeding for drought tolerance in maize (Zea mays L.). *American Journal of Plant Sciences*, *7*(14), 1858. https://doi.org/10.4236/ajps.2016.714172

Massino, A. I., Boboev, F. G., Nazarov, H., & Ezhov, M. N. (2013, April, 9-13). Breeding and seed production of corn in Uzbekistan. *Book of Proceedings I International Applied Science conference "Gene pool and plant breeding in 2 volumes. Vol. 2 Field crops*, 313-319. [in Russian]

Oleynikova T. V., & Osipov Yu. F. (1976). Determination of drought tolerance of wheat and barley varieties, lines and hybrids of maize by seed germination on sucrose solutions with high osmotic pressure. Methods for assessing plant resistance to adverse environmental conditions. Kolos, St.-Petersburg. [in Russian]

Palusa, S. G., Ali, G. S., & Reddy, A. S. (2007). Alternative splicing of pre-mRNAs of Arabidopsis serine/arginine-rich proteins: regulation by

hormones and stresses. *The Plant Journal*, *49*(6), 1091-1107. https://doi.org/10.1111/j.1365-313X.2006.03020.x

Panfilova, O. N., Chugunova, E. V., & Derunova, S. N. (2020). Source material for the selection of corn for drought tolerance. *The Agrarian Scientific Journal*, (2), 29-37. [in Russian]. https://doi.org/10.28983/asj.y2020i2pp29-37

Prodan A.V., Zatula V.I. (2009). Review of the researches on study of droughts and mitigation of them negative influence. *Physical geography and geomorphology*, (57), 157-161. [in Ukrainian]

Prysiazhniuk, L., Honcharov, Y., & Piskova, O. (2018). Identification of drought-resistant maize lines by DNA markers. *Book of Proceedings International GEA (Geo Eco-Eco Agro) Conference "GREEN ROOM SESSIONS 2018"*, 88-93.

Rorat, T. (2006). Plant dehydrins - tissue location, structure and function. *Cellular and Molecular Biology Letters*, *11*(4), 536-556. https://doi.org/10.2478/s11658-006-0044-0

Rotari, E., Rotari, A., Comarova, G., Bounegru, S., & Fratea, S. (2018). Methodological principles for selection algorithm elaboration of corn drought-resistant forms. In *Aspecte ameliorative în ameliorarea plantelor* (pp. 150-159). [in Russian]

Satarova, T. M., Filipov, H. L., Bielikov, Ye. I., & Kuprichenkova, T. H. (2016). *The breeding of new heat-resistant lines maize heterosis group Lancaster. Bulletin Institute of agriculture of steppe zone NAAS of Ukraine*, (10), 114-118. [in Ukrainian]

Tesfaye, K., Kruseman, G., Cairns, J. E., Zaman-Allah, M., Wegary, D., Zaidi, P. H., ... & Erenstein, O. (2018). Potential benefits of drought and heat tolerance for adapting maize to climate change in tropical environments. *Climate risk management*, *19*, 106-119. https://doi.org/10.1016/j.crm.2017.10.001

Valentovic, P., Luxova, M., Kolarovic, L., & Gasparikova, O. (2006). Effect of osmotic stress on compatible solutes content, membrane stability and water relations in two maize cultivars. *Plant Soil and Environment*, *52*(4), 184.

Yeremenko, O., Kalenska, S., Kalytka, V., & Malkina, V. (2017). Sunflower productivity depending on agrometheorological conditions of the Southern steppe of Ukraine. *Agrobiology*, 2, 123-130. [in Ukrainian]

Original Scientific paper
10.7251/AGRENG2002090O
UDC 575.1:636.2

DETECTION OF SELECTION SIGNALS IN CATTLE POPULATIONS BY PCA

Barbora OLŠANSKÁ*, Radovan KASARDA, Kristína LEHOCKÁ, Nina MORAVČÍKOVÁ

Slovak University of Agriculture, Department of Genetics and Animal Breeding Biology, Trieda A. Hlinku 2, 949 76, Nitra, Slovakia
*Corresponding author: baska.olsanska@outlook.com

ABSTRACT

The presented study provides a genome-wide scan of selection signals in cattle by principal component analysis (*PCA*). The aim was to identify SNP affected by intensive selection based on package *PCAdapt* implemented under software *R*. This analysis provided insight into the association between the SNP frequencies related to population differentiation. The four cattle populations were involved in the analysis (Slovak Spotted cattle, Ayrshire, Swiss Simmental and Holstein) with overall 272 of genotyped individuals. After applying quality control, the final dataset consisted of 35 675 SNPs, with an overall length of 2496.14 Mb and average space between adjacent SNP 70.03 ± 76.1 kb. After performing *PCA* analysis, the uniqueness of the breeds was revealed. On the other hand, a close genetic relationship and eleven SNPs affected by selection were found, with a position close to 162 genes involved in the various biological processes. The majority of genes were involved in the positive regulation of adenylate cyclase activity, embryo development and somatic diversification of immune receptors via somatic mutation. Several candidate genes for genetic control of the immune system (*DNAJB9*), muscle development (*SEPT7, TRIM32, ROCK1, NRAP, PZDZ8, HSPA12A* and *FGFR2*), milk production (*SOCS5, CD46*), reproduction *(LHCGR, EEPD1, FSHR*) and coat colour (*KIT*) were identified. Our results provide insights into the regions of the genome affected by the intensive selection of analysed cattle populations.

Keywords: *biological process, Bos Taurus, footprints of selection, PCAdapt, production traits.*

INTRODUCTION

Nowadays, cattle are one of the most important livestock species in the world. Cattle is significant because humanity benefits through their production of milk, meat, leather, and traction force. Since the domestication process, directional selection has caused different phenotypic and biological characteristics of different cattle breeds (Randhawa et al., 2016). In Slovakia, cattle breeding is part of a

closed agricultural system and a vital co-creator of the environment. Non-productive functions of cattle breeding significantly contribute to maintaining the cultural character of the country and its social function (Brestenský et al., 2015).
Bovine breeds that are considered local are a source of significant genetic variation because they may have alleles that allow them to adapt to the local environment and feed (Bahati et al., 2020). Directional selection has been focused on achieving the breeding objectives provided the individual's adaptation to the specific production environment (Duforet-Frebourg et al., 2015). Such an impact of selection has left distinct genomic signatures that can be used to retrospectively understand breeding objectives, detect economically important alleles, and potentially allow for a better understanding of biologically specific phenotypes (Joukharad et al., 2019; Moradian et al., 2020).
For identification of the selection impact on genome architecture and detection of particular candidate genomic regions affected by intense selection, various analytical methods have been developed. Previous studies in cattle provide information about selection which affected genome variation and architecture. Selection for individual breeds led to the fixation of specific variants, which in comparison with others became specific signatures for each breed. Such selection signals were observed in different populations using several methods, e.g. based on the allelic frequency spectrum, differentiation of populations (F_{ST}) an extent of linkage disequilibrium (Mustafa et al., 2018; Cheruiyot et al., 2018; Moravčíková et al., 2017). Using principal component analysis (PCA), whole-genome selection scans can be performed. The standard F_{ST} index of genetic differentiation between populations can be considered as the variance ratio explained by the major principal components (Duforet-Frebourg et al., 2015).
The objectives of this study were to describe population structure, identify footprints of selection based on PCA analysis as well as genes in particular genomic regions and their function in the biological processes in cattle with a focus on the genome of Slovak Spotted, Swiss Simmental, Holstein and Ayrshire breeds.

MATERIAL AND METHODS

For this analysis, 272 genotyped animals belonging to four cattle breeds (Slovak Spotted - SS, Swiss Simmental - SIM, Holstein – HOL, Ayrshire – AYR) were used. The final dataset included data for 85 SS animals genotyped by the Illumina BovineSNP50v2 BeadChip (bulls) and ICBF International Dairy and Beef v3 (dams). The genotypes of other breeds: 78 SIM, 99 HOL and 10 AYR described in McTavish et al. (2013) were used. After data merging, quality control was done according to Moravčíková et al. (2017).
Outlier loci signalising selection signals in particular genomic regions were identified based on the principal component analysis (PCA) by package *PCAdapt* (Luu et al., 2020). Genetic differentiation within and across analysed breeds was tested based on the Mahalanobis distance approach. The Mahalanobis distance is a multi-dimensional method to find out the distance of a point from the mean based

on the *Z*-scores gained from the regression of SNPs with K principal components. The Mahalanobis distance is defined as:

$$D_j^2 = \left(z_j - \bar{z}\right)^T \Sigma^{-1} (z^j - \bar{z})$$

where Σ is the (K × K) covariance matrix of the z-scores and $\bar{z}$ is the vector of the K z-score means. The Mahalanobis distance had to be transformed to P-values to achieve a real value of number between 0 and 1. The P-values less than 0.05 was considered as outliers signalising significant impact of selection on the particular region in the autosomal genome (Luu et al., 2020). For visualisation of p-values was used package *qqman* under R software environment (Turner 2017). After targeted the outlier loci, genes involved in various biological processes (Genome data viewer, WebGestalt) and QTLs (CattleQTLdb) were identified.

RESULTS AND DISCUSSION

The final dataset consisted of 35 675 SNP with average space between adjacent SNP 70.03 ± 76.01 kb and the overall length of the genome was 2496.14 Mb. Using *PCA* method, the genetic structure of the analysed populations was defined and a whole-genome scan of SNPs associated with selection was performed. Obtained individual membership probabilities indicated grouping of animals into the genetic clusters concerning specific breeding objectives of each breed (Figure 1). The Holstein and Swiss Simmental populations created separate genetic clusters. Figure 1 indicated that Slovak Spotted and Ayrshire populations were partially linked together probably due to use of Ayrshire in the grading-up of Slovak Spotted.

Huson et al. (2020) reported for Jersey cattle bred in different areas homogeneity despite a various geographic origin, compared with Holstein and Guernsey. In contrary, Ahmad et al. (2020) found among breeds Holstein, Jersey and Brown Swiss high degree of differentiation depending on the geographical origin. Cheruiyot et al. (2018) observed dispersion of Tanzanian crossbred cattle toward Northern European taurine breeds like Holstein, Norwegian Red and Friesian. These results confirm our suggestions that close genetic relationships among analysed breeds arise most likely due to cross-breeding for improvement of Slovak Spotted performance traits. The subsequent analyses of selection signatures showed that the artificial selection acted mainly in the genomic regions associated with milk and meat production, reproduction and exterior characteristics. Signatures of intensive selection in the genome are highlight in Table 1.

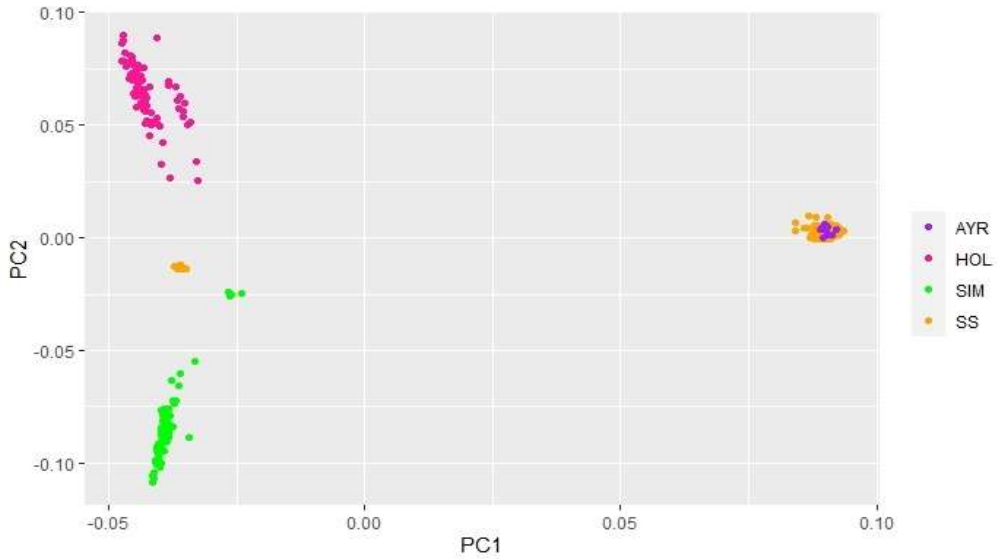

Figure 1. Structure of analysed populations used to determine SNPs associated with selection (Slovak Spotted - SS, Swiss Simmental - SIM, Holstein – HOL, Ayrshire – AYR),

Table 1. Description of 10 regions affected by intense selection

CHR	Position (Mb)	QTL
4	56.48 - 63.12	height (yearling), carpic acid content, clinical mastitis, milk palmitoleic content, parasites mean of natural logarithm, milk protein percentage, muscle carnosine content, intramuscular fat
6	69.88 - 80.89	milk yield, milk protein yield, conception rate, milk fat yield
8	101.50 - 110.65	milk fat percentage, milk protein percentage, milk butyric acid content, milk caproic acid content, milk caprylic acid content, milk capric acid content, milk lauric acid content, milk myristic acid content, milk palmitic acid content, milk margaric acid content
11	23.72 - 32.90	shear force, marbling score, milk palmitic, lean meat yield
13	68.63 -71.01	teat length, first service conception, conception rate, milk caproic acid content, milk caprylic acid content, milk capric acid content, milk myristoleic acid content, milk palmitoleic acid content
16	70.99 - 79.58	milk kappa-casein percentage, first service conception, conception rate, conformation score, social separation - standing alert, milk protein percentage, muscle phosphorus content, interval to first estrus after calving
22	43.77 - 45.49	milk yield, conception rate, dairy form, PTA type, teat placement - front, udder attachment, udder height, rump width, udder cleft

23	30.16 - 30.71	milk protein yield, milk conjugated linoleic acid content, milk protein percentage, milk yield, milk mid-infrared spectra, immunoglobulin G level
24	29.41 - 37.19	cooking loss, oleic acid content, stillbirth, body weight (yearling), fat thickness at the 12th rib, body temperature, respiratory rate, milk tridecylic acid content, bovine respiratory disease susceptibility, udder depth
26	35.59 - 49.14	milk protein yield, milk fat yield, udder width, milk kappa-casein percentage, milk glycosylated kappa-casein percentage, conformation score

Manhattan plot (Figure 2) showed the SNP outliers identified using a whole-genome scan for selection signatures by principal component analysis. In the affected regions, 162 genes affected immune system, muscle development, milk production, reproduction and coat colour were identified. Fontanesi et al. (2010) reported that gene *KIT* might affect the coat colour. Gene *DNAJB9* was associated with inflammatory, immune and stress response in lambs (Sabino et al., 2018). Li et al. (2020) observed that gene *EEPD1* was associated with meat quality and reproduction traits in Holstein bulls. Saatchi et al. (2014) find out that gene *SEPT7* was a candidate gene for QTL affected body weights in Maine-Anjou cattle. Bongiorni et al. (2016) observed that gene *TRIM32* play a role in regulating skeletal muscle differentiation and regeneration of adult skeletal muscle in Maremmana and Chianina cattle. Gene *SOCS5* was distinctly expressed during the lactation in Australian dairy breed (Arun et al., 2015). Wohlres-Viana et al. (2017) reported that gene *LHCGR* control LH effect during follicle growth and ovulation. Gene *FSHR* was associated with promoting follicle of Yaks (Xia et al., 2020). Wang et al. (2014) suggested that polymorphism of gene *CD46* is associated with the occurrence of mastitis in dairy cow. Gene *NR5A2* is included in the processes of spermatogenesis in mice (Liu et al., 2016). Taye et al. (2017) reported relatedness of gene *ROCK1* with intramuscular fat. Genes *NRAP, PZDZ8* and *HSPA12A* were associated with a muscular function (Masoudi et al., 2008). Akizawa et al. (2016) reported that gene *FGFR2* was involved in the regulation of inner cell mass development and blastocyst formation in cattle.

Compared to our results, Mustafa et al. (2018) reported for *Bos Indicus* 11 outlier loci with candidate genes associated with the immune system, muscle growth and some economically important traits like body growth and longevity. Cheruiyot et al. (2018) observed for dairy cattle in Tanzania candidate regions on chromosomes 6, 7, 14, 18 and 20. Flori et al. (2009) find selection signatures in 16 genomic regions for French dairy cattle. These findings indicated that the occurrence of selection signatures in genomic regions was caused by improve production characteristics or adapt to the environment. Genes involved in various biological processes (Table 2) have been identified in genomic regions under selection pressure. Observed biological processes suggested that the genome was affected by the artificial as well as natural selection to adapt specific production environment.

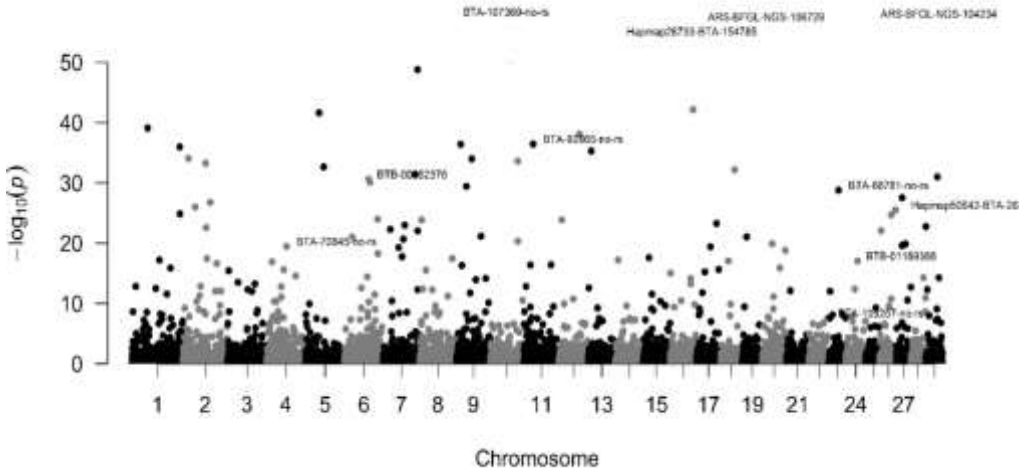

Figure 2. Manhattan plot of genomic regions indicating the SNPs associated with selection

Table 2. Biological processes of genes identified in genomic regions of outlier's loci in analysed populations

Gene Set	Description	p-value	Gene Code
GO:0051096	positive regulation of helicase activity	0.0005	*MSH2, MSH6*
GO:0051095	regulation of helicase activity	0.0007	*MSH2, MSH6*
GO:0045762	positive regulation of adenylate cyclase activity	0.0010	*FSHR, LHCGR*
GO:0009790	embryo development	0.0011	*HOPX, LAMB3, MIN1, MSH2, PLCG1, RBBP8, SEPT7, SIX3, TBX20, TOP1, WHRN*
GO:0051239	regulation of multicellular organismal process	0.0013	*AFAP1L2, BMPER, BRINP1, HOPX, KDR, LRRN3, MIB1, MSH2, MSH6, NMU, PLCG1, PPM1B, PRKCE, REST, SEPT7, SIX3, SOCS5, TBX20, TLR4, TRIM32*
GO:0007190	activation of adenylate cyclase activity	0.0013	*FSHR, LHCGR*
GO:0002566	somatic diversification of immune receptors via somatic mutation	0.0013	*MSH2, MSH6*
GO:0016446	somatic hypermutation of immunoglobulin genes	0.0013	*MSH2, MSH6*
GO:0071229	cellular response to acid	0.0020	*BRINP1, KDR, PRKCE, YES1*

	chemical		
GO:0048015	phosphatidylinositol-mediated signalling	0.0021	*EXOC1, FSHR, KCNH1, KDR*
GO:0048017	inositol lipid-mediated signalling	0.0023	*EXOC1, FSHR, KCNH1, KDR*
GO:0008340	determination of adult lifespan	0.0031	*MSH2, MSH6*
GO:0051240	positive regulation of multicellular organismal process	0.0036	*AFAP1L2, BMPER, BRINP1, KDR, LRRN3, MSH2, MSH6, NMU, PLCG1, PRKCE, SOCS5, TBX20, TRIM32*
GO:0045830	positive regulation of isotype switching	0.0036	*MSH2, MSH6*
GO:0045761	regulation of adenylate cyclase activity	0.0042	*FSHR, LHCGR*

CONCLUSION

The presented study confirmed that the genome of Slovak Spotted cattle was affected mainly by cross-breeding with Ayrshire cattle in the past to increase milk production. The genetic differences among analysed breeds were represented by ten genomic regions significantly affected by selection. The results showed that in the genome of analysed breeds specific alleles associated with adaptation to the production environment, performance traits and reproduction were fixed. The genes identified in the affected regions were involved in various processes, including regulation of immune system (*DNAJB9*), muscle development (*SEPT7, TRIM32, ROCK1, NRAP, PZDZ8, HSPA12A* and *FGFR2*), milk production (*SOCS5, CD46*), reproduction (*LHCGR, EEPD1, FSHR*) and coat colour (*KIT*). This study provided information about the breeding history of Slovak Spotted cattle and offer a basis for further studies to complement the knowledge about the associations between the genotype and phenotype of the Slovak Spotted cattle.

ACKNOWLEDGEMENT

This study was supported by the Slovak Research and Development Agency (APVV-14-0054 and APVV-17-0060).

REFERENCES

Ahmad, S.F., Panigrahi, M., Chhotaray, S., Pal, D., Parida, S., Bhushan, B.,Gaur, G.K., Mishra, B.P., Singhc, R.K. (2020). Revelation of genomic breed composition in a crossbred cattle of India with the help of Bovine50K BeadChip, Genomics, 112(2), (1531-1535).

Arun, S.J., Thomson, P.C., Sheehy, P.A., Khatkar, M.S., Raadsma, H.W., Williamson, P. (2015). Targeted Analysis Reveals an Important Role of JAK-STAT-SOCS Genes for Milk Production Traits in Australian Dairy Cattle, Front.Genet.

Bongiorni, S., Gruber, C.E.M., Bueno, S., Chillemi, G., Ferrè, F., Failla, S., Moioli, B., Valentini, A. (2016). Transcriptomic investigation of meat tenderness in two Italian cattle breeds, Animal Genetics, 47(3).

Brestenský, V. (2015) Chov hospodárskych zvierat, Národné poľnohospodárske a potravinárske centrum - Výskumný ústav živočíšnej výroby Nitra.

Cheruiyot, E.K., Bett, R.C., Amimo, J.O., Zhang, Y., Mrode, R., Mujibi, F.D.N. (2018). Signatures of Selection in Admixed Dairy Cattle in Tanzania, Front. Genet.

Duforet-Frebourg, N., Luu, K., Laval, G., Bazin, R., Blum, M.G.B. (2015). Detecting Genomic Signatures of Natural Selection with Principal Component Analysis: Application to the 1000 Genomes Data, Molecular Biology and Evolution, 33(4), (1082-1093).

Flori, L., Fritz, S., Jaffrézic, F., Boussaha, M., Gut, I., et al. (2009). The genome response to artificial selection: a case study in dairy cattle, PloSone, 4(8): e6595.

Fontanesi, L., Tazzoli, M., Russo, V., Beever, J. (2010). Genetic Heterogeneity at the Bovine KIT Gene in Cattle Breeds Carrying Different Putative Alleles at the Spotting Locus, Anim Genet., 41(3), (295-303).

Huson, H.J., Sonstegard, T.S., Godfrey, J., Hambrook, D., Wolfe, C., Wiggans, G., Blackburn, H., VanTassell, C.P. (2020). A Genetic Investigation of Island Jersey Cattle, the Foundation of the Jersey Breed: Comparing Population Structure and Selection to Guernsey, Holstein, and United States Jersey Cattle, Front. Genet.

Joukharad, R., Daetwyler, H.D., Gendall, A.R., Hayden, M.J. (2019). Artificial selection causes significant linkage disequilibrium among multiple unlinked genes in Australian wheat, Evolutionary Applications, 12(8).

Li, Y., Wang, M., Li, Q., Gao, Y., Li, Q., Li, J., Cao, Y. (2020). Transcriptome profiling of longissimus lumborum in Holstein bulls and steers with different beef qualities, PLoS ONE, 15(6): e0235218.

Liu, C., Qian, P., Yang, L., Zhang, L., Chen, C., He, M., et al. (2016). Pubertal exposure to di-(2-ethylhexyl)-phthalate inhibits G9a-mediated histone methylation during spermatogenesis in mice, Arch. Toxicol., 90, (955–969).

Luu, K., Blum, M., Privé, F., Bazin E., Duforet-frebourg, N. (2020) Fast Principal Component Analysis for Outlier Detection.

Masoudi, A.A., Uchida, K., Yokouchi, K., Ohwada, K., Abbasi, A.R., Tsuji, T., Watanabe, T., Hirano, T., Sugimoto, Y., Kunieda, T. (2008). Linkage mapping of the locus responsible for forelimb-girdle muscular anomaly of Japanese black cattle on bovine chromosome 26, Animal Genetics, 39(1).

McTavish E.J, Decker, J.E., Schnabel, R.D., Taylot, J.F., Jillis, D.M. (2013). New world cattle show ancestry from multiple independent domestication events, PNAS, 110(15): (1398–1406).

Moradian, H., Koshkoiyeh, A.E., Mohammadabadi,M., Fozi, M.A. (2020). Whole genome detection of recent selection signatures in Sarabi cattle: a unique Iranian taurine breed, Genes & Genomics, 42, (203-215).

Moravčíková, N., Kukučková, V., Mészáros, G., Sölkner, J., Kadlečík, O., Kasarda, R. (2017). Assessing footprints of natural selection through PCA analysis in cattle, Acta fytotechn zootechn, 20(2), (23-27).

Mustafa, H., Khan, W.A., Sonstegard, T., Li, Y., Ain, N.U., Ajmal, A. (2018). Genome-Wide Identification of Natural Selection Footprints in Bos Indicus Using Principal Component Analysis, Life Sci., 5(2), (67-72).

Randhawa, I.A.S., Khathar M.S., Thomson, P.C., Raadsma, H.W. (2016). A Meta-Assembly of Selection Signatures in Cattle, PLoS ONE 11(4): e0153013.

Saatchi, M., Schnabel, R.D., Taylor, J.F., Garrick, D.J. (2014). Large-effect Pleiotropic or Closely Linked QTL Segregate Within and Across Ten US Cattle Breeds, BMC Genomics, 15(1), (442).

Sabino, M., Carmelo, V.A.O., Mazzoni, G., Cappelli, K., Capomaccio, S., Ajmone-Marsan, P., Verini-Supplizi, A., Trabalza-Marinucci, M., Kadarmideen, H.N. (2018). Gene Co-Expression Networks in Liver and Muscle Transcriptome Reveal Sex-Specific Gene Expression in Lambs Fed With a Mix of Essential Oils, BMC Genomics, 19(1), (236).

Taye, M., Kim, J., Yoon, S.H., Lee., W., Hanotte, O., Dessie, T., Kemp, S., Mwai, O.A., Caetano-Anolles, K., Cho, S., Oh, S.J., Lee, H., Kim, H. (2017). Whole Genome Scan Reveals the Genetic Signature of African Ankole Cattle Breed and Potential for Higher Quality Beef, BMC Genet., 18(1), (11).

Turner, S. (2017). Q-Q and Manhattan Plots for GWAS Data.

Wang, X., Zhong, J., Yundong, G., Ju, Z., Huang, J. (2014). A SNP in Intron 8 of CD46 Causes a Novel Transcript Associated With Mastitis in Holsteins, BMC Genomics., 15(1), (630).

Wohlres-Viana, S., Arashiro, E.K.N., Minare, T.P., Fernandes, C.A.C., Grazia, J.G.V., Siqueira, L.G.B., Machado, M.A., Viana, J.H.M. (2017). Differential expression of LHCGR and its isoforms is associated to the variability in superovulation responses of Gir cattle, Theriogenology, 126, (68-74).

Xia, Y., Wang, Q., He, X.D., Chen, Y., JiGe, M.T., Zi, X.D. (2020). Cloning and Expression Analysis of the Follicle-Stimulating Hormone Receptor (FSHR) Gene in the Reproductive Axis of Female Yaks (Bos Grunniens), Domest Anim Endocrinol., 70, (106383).

Original Scientific paper
10.7251/AGRENG2002099S
UDC 628.3(497.2)

SOCIO-ECONOMIC AND BEHAVIORAL ASPECTS OF SLUDGE UTILIZATION IN BULGARIAN FARMS

Angel SAROV*, Daniela TSVYATKOVA

Institute of Agricultural Economics, Sofia, Bulgaria
*Corresponding author: angelsarov@abv.bg

ABSTRACT

The issue of sludge governance received from the wastewater treatment plants (WWTP) is extremely relevant and indisputably one of those discussed not only in Bulgaria, but also around the world. The positive role of sludge on the balance of humus as a result of activating the activity of soil microorganisms has also been proven. The aim of this article is to analyze the socio-economic and behavioral aspects of sludge utilization on farms. Extensive in-depth interviews have been conducted and summarized with farmers using and not using sludge in the Sofia region, aiming to gather complete information of production, economic, behavioral, organizational and other nature from farmers using and not using sludge. The main (economic, technological, behavioral, etc.) factors that influence the decisions on the use and non-use of sludge in agricultural production are identified. The results show that the effect of sludge utilization on crop yield is not instantaneous. It is established that there is a lag in revealing the benefits of this activity. Interviews conducted with farmers using sludge in their agricultural activities show twice the yields compared to conventional production. However, the application of sludge is accompanied by a number of challenges: public opinion, properties of sludge, as well as many issues related to the technological introduction of sludge in arable agricultural land.

Keywords: *agriculture, governance, sewage sludge, socio-economic aspects, Bulgaria.*

INTRODUCTION

The issue of sludge governance received from the WWTP is extremely relevant and indisputably one of the issues discussed not only in Bulgaria but also worldwide. The positive role of sludge on the balance of humus as a result of activating the activity of soil microorganisms has been proven. The socio-economic and behavioral aspects of the utilization of sludge obtained as a result of wastewater treatment have been studied in the scientific literature around the world.

A report published by RPA, Milieu Ltd and WRc for the European Commission, DG Environment (2008) states that at present not all impacts from sludge recovery

can be assessed. Palme et al. (2005) and Stenstrom et al. (2011) focus on socio-economic factors as determinants for farmers in the recovery of sewage sludge in wastewater treatment plants.

Currently in Bulgaria on the topic of WWTP sludge includes many studies related to the technological process, technology management and assessments of environmentally friendly and efficient use of WWTP sludge (Marinova and Tzolova, 2005; Baykov et al., 2013; Popova et al., 2017), without considering the influence of socio-economic factors.

The objective of the present paper is to identify the main economic, social and behavioral factors that encourage farmers to use sludge as a soil improver.

MATERIAL AND METHODS

The team developed a survey in the form of a structured questionnaire in three parts. The first covers questions with a general description of the interviewees. The second and third are aimed at farmers who use and do not use sludge, respectively. An analysis of the socio-economic and behavioral aspects in the utilization of sludge in agricultural holdings is made. During the period 2019-2020, in-depth interviews were conducted and summarized with farmers who use and do not use sludge in the Sofia region. The aim was to gather complete information on the production, economic, behavioral, organizational and other nature of farmers who use and do not use sludge. The analysis is based on a qualitative "picture" and summarized on quantitative data, given the restriction that is set - Sofia region. In some of the data differences and contradictions were found, but these are the real impressions of the interviewees in agricultural activity. They only reinforce some of the identified trends in practice.

RESULTS AND DISCUSSION

Characteristics of the surveyed farmers using sludge

According to the available information, there are seven farmers in the Sofia region, who use sludge. Their arable fields are located in the villages of Chepintsi, Svetovrachane, Lokorsko, Negovan, Buhovo, Seslavtsi, Stolnik and Grigorevo (Figure 1). The soils on which the sludge is used are diverse and include: chernozems – vertisols, chromic cambisols, gray luvisols, mollic cambisols, eutric fluvisols.

The largest producer cultivates 12 thousand decares of agricultural land. The other farmers cultivate an average of between 700 and 5,000 decares. The average age of farmers varies from 40-55 years. The farms are well provided with equipment, labor, good knowledge of the legislation and a positive attitude towards innovation in agriculture. All farmers have many years of experience in the industry for at least 10 years. The identified trends in sludge users will be divided, as follows:

Figure 1. Map of the conducted in-depth interviews with agricultural producers from Sofia region

Economic benefits

Interviews conducted with farmers using sludge in their agricultural activities show twice and in some cases up to three times higher yields compared to conventional production. This is additionally comparable to some challenges: public opinion, sludge properties, issues with technological input into agricultural land.

According to the interviewed farmers, about 40% of the total production costs are for fertilization – N, P and K. The farmers prove that sludge successfully replaces mineral fertilizers for a relatively long period of time - 5 years, during which they do not fertilize with mineral fertilizers, but continue to accumulate the benefits of the stock of sludge with minerals. Respondents say that the economic benefit is the elimination of costs of about € 60/ha per year for fertilization.

All farms communicate an additional benefit - the delivery of sludge is free from the treatment plant. The costs for plowing, depreciation of equipment, salary, consumables, etc. upon delivery of the sludge in the cultivated fields are paid by the WWTP.

Of cereals, it has been shown that maize is most strongly affected by sludge and the effect on yield is significant. Different effects on yield are reported for different soil types (Table 1;2;3), as follows:

Table 1. Maize yield with used sludge in different soil types

Maize	Chernozems – vertisols	Gray luvisols	Chromic cambisols	On average without the use of sludge
Yield (kg/dca)	1800	1600	1200	650

*Source: Author's elaboration based on the questionnaire survey results, 2019-2020.

Table 2. Effect of sludge on grain yield on Chromic cambisols

Chromic cambisols:	Wheat	Barley	Maize	Sunflower
Yield with used sludge (kg/dca)	700	750	1200	300
Yield without used sludge (kg/dca)	350	300	500	180

*Source: Author's elaboration based on the questionnaire survey results, 2019-2020.

Table3. Effect of sludge on yield in different crops in eutric fluvisols

Eutric fluvisols	Wheat	Sunflower
Yield with used sludge (kg/dca)	800	300
Yield without used sludge (kg/dca)	500	150

*Source: Author's elaboration based on the questionnaire survey results, 2019-2020.

According to Farmers, sludge helps twice as much to retain soil moisture. In addition, provided there is no sediment, the soil itself retains no more than 20-30% of the water, depending on the type of soil. In comparison, about 80% of moisture retention is lost in the soil when there is no sediment. One of the key advantages of the influence of sludge on soil fertility is its ability to retain water and improve moisture retention. According to their calculations and observations, the sludge retains water 6 times more. This is an extremely important condition for harvesting and development of plants, given that for the period 2008-2018 there is a reduction of precipitation in 2.5 times in the region of Sofia. The effect of the sludge on the soil is visualized as a "sponge", and in addition the soil becomes looser. At the same time, given that the year is rainy, this is a sign that there will be better yields. In addition, the soil is easier to cultivate, which also affects the load on the tractors during plowing. The effect on wheat and barley is established after 3 years from the introduction of the sludge.

In addition, the following should be noted: maize grown with imported sludge has larger cobs, and wheat has a larger grain. Maize grown with the use of sludge has a significantly better developed stem, higher, with better developed leaf mass, larger cobs compared with that grown without sludge.

Social aspects

The biggest problem is the socio-psychological factor and the perception of the general public - the specific unpleasant smell emitted by the sludge during its introduction into the cultivated fields and resentment among the population. The passage of trucks through the settlements; the long plowing period; local government intervention; police; Complaints, anxiety, are part of the problems of farmers. The farmers say that the dry sludge does not emit such a specific smell.

It has been identified that the more liquid the state of the sludge, the more pungent the smell. Their concern comes from the fact that as a result of agro-technical requirements, they have a window of two months in the summer - these are the months from July to August, after harvest (after harvest), during which period a perfect plan must be made for days the introduction of the sludge, i.e. after harvesting, applying the sludge, spreading it on the field and plowing immediately. This is the next critical moment. If it is not plowed immediately and does not mix with the soil, especially when the wind increases and at high humidity, an unpleasant smell is released.

The farmers say that when the climate is dry - it does not smell, and when it is humid, the specific smell increases. However, everyone is aware that most often about 90% of the sludge content is the result of waste caused by human activity. Farmers are worried that if sludge is widely used in agriculture in the Sofia region, the amount of sludge during the plowing period "will not be enough for everyone". Perhaps this is the reason why many of them do not share with other farmers the positive effect of sludge.

Behavioral aspects

All interviewees are unanimous, that after plowing the sediment in the soil, its structure is compacted, as a result of which the soil is significantly compacted and fails to recover in the first year, especially if it was wet. This greatly hinders germination and slows down the physiological development of plants if sown. Everyone shares, that in the first year the sludge does not have the expected effect on the yield. It is generally recommended that in practice, after the application of the sludge, in the first year, the field should be set aside to restore aeration and improve the soil structure. This can happen in the second year. Farmers who use sludge strongly express their support and trust the officials of the treatment plant for technical assistance. In the area, producers have studied the presence of heavy metals and the content of minerals in the soils intended for cultivation. For the most part, soils are acidified with the presence of iron, heavy metals, lead. Farmers say they are doing analysis and soil samples and seeking the help of licensed laboratories. It is important for them to monitor the amount of N, P and K in the soil. They are interested in what substances the cultivated plant has "absorbed" from the soil. But so far they have not studied the mineral composition of crops and the presence of heavy metals in the grain, because they are not required by the legal framework in Bulgaria. Studies have been performed on maize for silage and the nitrate content is within the permitted norms. They found that the presence of zinc

in the sludge was a critical element. One of the producers shared that he found that after sunflower and corn - not to apply the sludge, which was not confirmed by the other interviewees. Most agreed that the best crop for sludge absorption is corn. Others mentioned that it was not good to use wheat as the first crop in the crop rotation. Quite different opinions have emerged here, on the basis of which no definite opinion can be taken. Apparently, each farmer has other influencing factors that have been spared or have not yet been identified by them. Agricultural experience has taught them that it takes 60 days to absorb mineral fertilizers into the soil, and the nutrients from the sludge are immediately absorbed by the plants.

Attitudes and summarized opinions of the group of farmers who do not use sludge.
These are agricultural producers who grow land massifs (from 600 dca to 6000 dca) and are leading tenants for their regions. The main crops grown are: corn, wheat, sunflower and barley. There are farmers who specialize in growing mainly bread varieties of wheat.
The average age of farmers is about 40-55 years, actively working on farms, with extensive practical experience theoretical knowledge in agricultural science. They have a good technical provision of the farms with production equipment. They work with long-term partners for the realization of the production on the market.
Definitely everyone mentions that they are familiar with the use of WWTP sludge. It is noteworthy that everyone knows each other well and has observed changes in the harvest and yield of their colleagues using sludge. For most farmers, what they have heard, felt and observed and what worries them most is the separation of the specific smell and negative public opinion from it. Some of them even say that public opinion is leading for them, for fear that a large part of the people would withdraw to rent their land to them.
Many of them know that this also changes the structure of the soil, enriching and improving it. They share that for them this is not sludge, but it is a product that improves soil fertility.
It is noteworthy that some farmers have read scientific articles about sludge and for them the dried and treated sludge should not have a problem with the smell when plowing it into the soil.
Farmers have been informed by farmers using sludge that in the first year the sludge must be placed on land where corn is grown and not wheat. They have seen that corn in the first year does not give the desired yield (it sprouts and reaches a maximum height of 40-50 cm from the ground). To the assessment of the socio-economic impact of sludge in agricultural activity. Farmers believe that attending specialized information seminars will provide more clarity on the issue of WWTP sludge; informal conversation between farmers; television; internet and social networks and more publicity. At this stage in Bulgaria there is no specialized literature on the technology and the effect of sludge fertilization in agriculture, which is a guide for farmers. At the present stage they learn from practice, mutually and often with contradictory findings. We decided to test the readiness of farmers and their ability to calculate the risk, using something new (sludge to

improve soil fertility) on their farm - most of them are ready to sign a contract with WWTP to test half of their land and gradually to close the whole production cycle. In the interviews we identified respondents (mainly agricultural cooperatives with a large number of members) for whom, the sludge becomes a controversial point, in terms of the members' concerns that it could affect human and animal health. Agricultural cooperatives are extremely clear that will not use sludge. This categoricalness comes from the attitudes of the older population, which are the predominant members of the cooperative. The opinion imposed in the society is that the sludge is a waste product from a wastewater treatment plant, which is contrary to the principle of cooperatives before the society - their social role.

CONCLUSIONS

Preliminary observations show (also confirmed by interviews) that the effect of sludge recovery is not instantaneous. It is established that there is a lag in revealing the benefits of this activity. The recovery of sludge in agriculture should be considered as one of the possibilities for recovery of this waste product by WWTP in the long run, among other alternatives. Interviews conducted with farmers using sludge in their agricultural activity show twice the yields compared to conventional production. This also reveals the potential of the results. However, the application of sludge is accompanied by a number of challenges: public opinion, properties of sludge, issues related to the technological introduction of sludge in arable fields. The main (economic, technological, behavioral, etc.) factors that influence the decisions on the use and non-use of sludge in agricultural production are identified. The effect of sludge recovery in agriculture undoubtedly has a positive role to play. What will be their future as an element of the bio-economy is a question that depends on future European policies.

ACKNOWLEDGMENTS

This work was supported by the Bulgarian Ministry of Education and Science under the National Research Programme "Healthy Foods for a Strong Bio-Economy and Quality of Life" approved by DCM, 2018, WP Component 4 "Bioeconomics, Food Systems and Integrated Regional Development" WP. 4.2 Regional ecosystems for bioeconomics and WP. 4.4 Research on the knowledge base and technological expertise needed to serve the sectors of regionally specialized bioeconomies.

REFERENCES

Baykov, Popova, Zaharinov, Marinova-Garvanska, Kaleva, Kirov. (2013). Microbiological evaluation of sewage sludge in terms of possibility of applications in soil as a fertilizer. In: Proceedings on the International Conference on Geoethics. Association of Geoscientists for International Development, Pribram. ISBN 9788090499348.

Milieu Ltd, WRC and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4 / ETU / 2008 / 0076r.

Popova, Zaharinov, Gentcheva, Pejtchinova, Marinova-Garvanska, Baykov. (2017). Microbiological Assessment of Sewage Sludge in Terms of Use as a Fertilizer - Energy Solutions to Combat Global Warming, 2017, p. 329-337, Springer, Cham.

Stenstrom, Sahachaisaeree and Stenstrom (2011). Socio-Economic Criteria for Wastewater Treatment System Selection: a Case of Municipality Contextual Determinants in Thailand, Proceedings of the Water Environment Federation.

Tzolova, V., Marinova, S. (2005). Agroecological effectiveness of organic and industrial waste utilization for reclamation. Journal of Balkan Ecology, 2005, vol.8, N 3:311-316.

Ulrika Palme, Margareta Lundin, Anne-Marie Tillman, Sverker Molander (2005). Sustainable development indicators for wastewater systems – researchers and indicator users in a co-operative case study Resources, Conservation and Recycling 43 (2005) 293–311.

Original Scientific paper
10.7251/AGRENG2002107K
UDC 631.41

EVALUATION OF SOIL QUALITY PARAMETERS IN SILVOARABLE SYSTEMS

Maria KOKKORA[1*], Michael VRAHNAKIS[2], Vassiliki KLEFTOYANNI[1]

[1]University of Thessaly, Volos, Greece
[2]Department of Forestry, Wood Sciences and Design, University of Thessaly, Karditsa, Greece
*Corresponding author: mkokkora@gmail.com

ABSTRACT

Agroforestry is considered a sustainable cultivating methodology in comparison to intensified and one-dimension agriculture, resulting in higher yields, socio-economic benefits and environmental protection as well. The silvoarable systems constitute classification of the agroforestry systems that involve crops and trees in the same spatiotemporal scales. One of the most important benefits related to the productivity of silvoarable systems is the maintenance or improvement of soil quality. In the present study, qualitative characteristics of soils in traditional silvoarable systems in the area of Mouzaki, central Greece, were studied through the determination of basic soil parameters, including the organic matter content, total nitrogen, exchangeable potassium and available phosphorus. All systems under investigation were characterised as boundary hedgerows (livefences). The trees in the hedgerows may include mulberry, wild pear, wild walnut, and other wild tree types typical of the Mouzaki landscape, whereas the understorey crops were both arable and horticultural. Within the research areas, the effect of the trees on the concentration of the selected soil parameters was investigated. Soil samples were collected in all systems at two depths (0-30 and 30-60 cm) and at three distances from the selected trees, corresponding to half, twice, triple or quadruple the tree canopy width. The results of the research provided evidence of C sequestration in all soils under investigation, thus indicating the positive effect of agroforestry systems on the environment.

Keywords: *Traditional agroforestry systems, Silvoarable systems, Soil fertility, Organic matter, Macronutrients.*

INTRODUCTION

Agroforestry is a dynamic natural resource management system, which results in diversified and sustainable production via the integration of trees on farms and in the agricultural landscape, leading to social, economic and environmental benefits (FAO, 2015). The silvoarable systems constitute classification of the agroforestry systems that involve crops and trees in the same spatiotemporal scales. Agroforestry systems can deliver a wide range of ecosystem services and

environmental benefits, including biodiversity conservation, carbon sequestration, soil enrichment and water and air quality improvement (Jose, 2009). Soil conservation is one of the most important promises of agroforestry in temperate regions (Nair, 2011).

The role of trees is multiple, as on the one hand, they can offer products, such as timber, firewood, food for humans and animals, and on the other hand, services, such as soil protection from erosion, soil fertility, weed control, shading for animals and humans and habitat provision for wildlife (Schultz *et al.*, 1987). Trees may have several other positive effects on arable productivity, including among others, reduction of evaporative water losses by acting as windbreaks, lifting of drainage water to the upper soil horizons, reduction in crop transpiration through shading especially in arid areas, and protection against ground frosts in colder climates (Eichhorn *et al.*, 2006). Trees may also improve soil physical, chemical and biological properties through the addition of significant amount of above and belowground biomass and releasing and recycling nutrients in agroforestry systems (Eichhorn *et al.*, 2006; Nair, 2011).

Traditional agroforestry systems in Greece cover an estimated area of approximately 3 million hectares, or 23% of the whole country (Papanastasis *et al.*, 2009). Silvoarable systems show great diversity in Greece, as a large variety of combinations of trees and crops exist, and trees are either dispersed through the fields, or at margins, as boundary hedgerows (Eichhorn *et al.*, 2006). Most traditional agroforestry systems in Greece appear unorganized, rather as remnants (Vrahnakis *et al.*, 2014). The Municipality of Mouzaki in central Greece is one of the areas where traditional silvoarable systems are still maintained. However, they are gradually being abandoned in the upland, as a significant portion of the population moves to towns and cities in the lowland. On the other hand, in the lowland silvoarable systems tend to be replaced by crop monocultures, thereby decreasing soil and water quality and deteriorating landscape values (Vrahnakis *et al.*, 2016).

The aim of the present study was to evaluate qualitative characteristics of soils of traditional silvoarable systems in the area of Mouzaki through the determination of basic soil parameters, including organic matter content, total nitrogen, exchangeable potassium and available phosphorus.

MATERIALS AND METHODS

The study took place in three cultivated fields, located in the Municipality of Mouzaki, on the southwestern edge of the Thessalian plain, in central Greece, during the time period between June 2019 and February 2020. The fields under investigation are traditional smallholder silvoarable systems, in the form of boundary hedgerows (livefences).

The first field (Area 1) was located in the lowland, at an altitude of approximately 180 m. The understorey crop was vine, whereas the hedgerow included a variety of fruit tree species, such as wild figs, pear, and apple, and also mulberries. The other two fields were located in the upland, at an altitude of approximately 480 m. The

second field (Area 2) was a young walnut orchard. At the time of sampling, the walnuts were 6 years of age. Walnuts planting distance was 10 x 10 m, with no intercropping. The hedgerow consisted predominantly of wild oaks and wild walnuts. In the third field (Area 3), the understorey crop was clover and the hedgerow included a mixture of wild trees, predominantly wild oak, walnut, and pear, and also blackberries.

The effect of the hedgerow trees on the concentration of selected soil parameters was investigated. In each field, three trees were selected on the same one side of the hedgerow. Mean canopy width were 7.9, 13.0 and 12.1 m for Areas 1, 2 and 3, respectively. For each one of the three trees, soil samples were collected along the line starting from the tree and directed vertically to the hedgerow, at three sampling points, corresponding to a distance of half, twice, triple or quadruple the tree canopy width (Figure 1). At each sampling point, soil samples were collected at the depths of 0-30 cm and 30-60 cm.

Soil samples were air-dried, ground, sieved (2 mm) and analyzed for texture (Bouyoucos method), concentration of organic matter (Walkley-Black method), total N (Kjeldahl method), exchangeable K (ammonium acetate method) and available P (Olsen method).

The data sets were analyzed using the statistical software SPSS version 26 (IBM Corp., Armonk, N.Y., USA). ANOVA was performed at a significance level of 0.05 and means were compared by Duncan test.

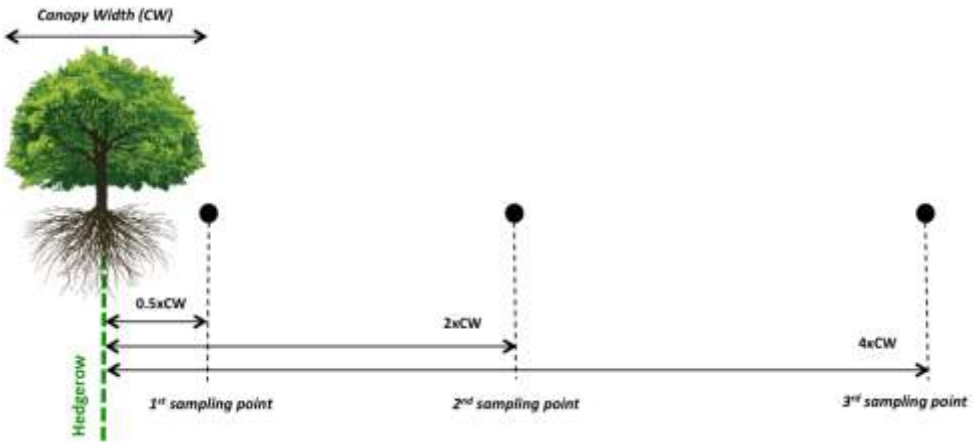

Figure 1. Schematic general layout of the soil sampling points per tree on the hedgerow.

RESULTS AND DISCUSSION

The soil texture of the first field in the lowland was clay loam in both the upper (0-30 cm) and lower (30-60 cm) layer. In the upland, both fields were of sandy clay loam texture, also in both layers.

All soil properties under investigation, i.e. organic matter content, total N, available P and extractable K, were found not to be significantly influenced by the distance

of the sampling point from the tree row, in all three fields. Oelbermann and Voroney (2007) also found that after 13 years of alley cropping in a silvoarable system in Southern Canada, soil organic C and N pools did not differ significantly with distance from the tree row. Work by Gikas *et al.* (2016) in Northeastern Greece, also showed no statistically significant difference between distances from the tree row for Olsen P.

Soil organic matter content (OM) was significantly higher in the upper layer (0-30 cm) than in the lower layer (30-60 cm) (Figure 2), indicating accumulation of organic material in the upper horizon. The effect of depth on soil OM was particularly evident in the upland fields (Areas 2 and 3). The increase in soil organic matter content with elevation, can be explained by the change of climatic conditions with altitude (Ramesh *et al.*, 2019).

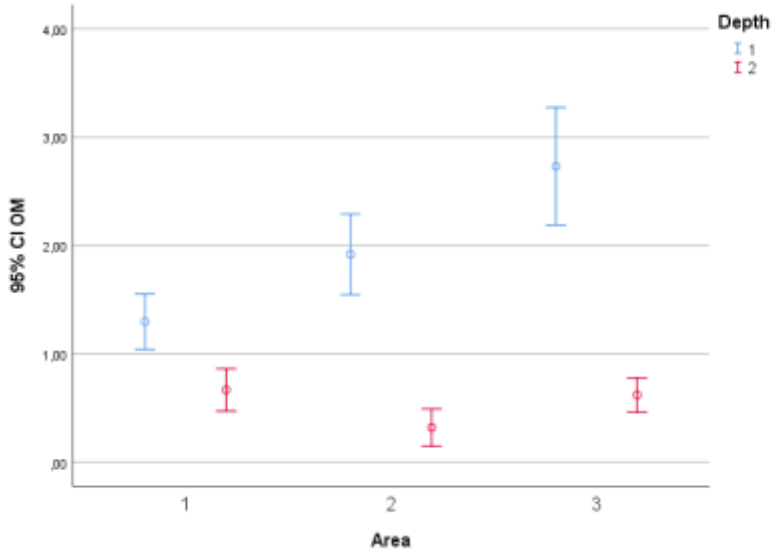

Figure 2. Mean and confidence interval 95% of soil organic matter content (%) for depths 1: 0-30 cm and 2: 30-60 cm from areas: 1, 2 and 3.

Soil total N followed the same trends with OM (Figure 3). The simultaneous increase in soil organic matter and N suggests organic C sequestration in the soil (Horwath and Kuzyakov, 2018), thus resulting in important environmental benefits.

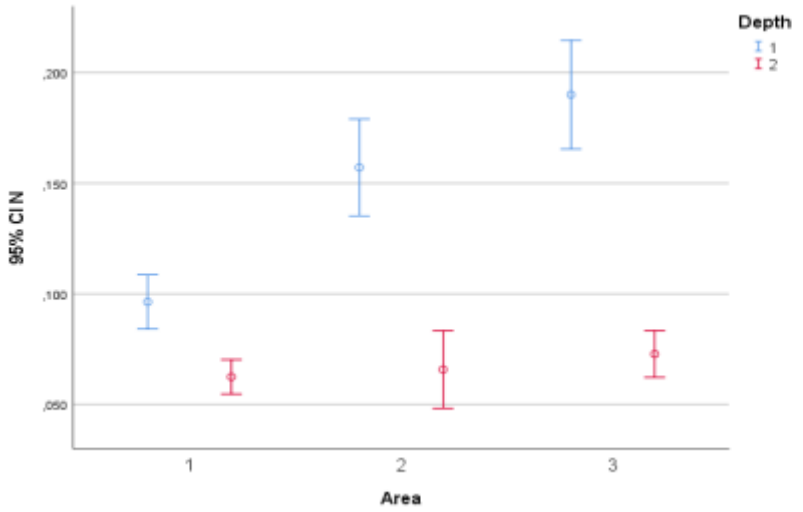

Figure 3. Mean and confidence interval 95% of soil total N (%) for depths 1: 0-30 cm and 2: 30-60 cm from areas: 1, 2 and 3.

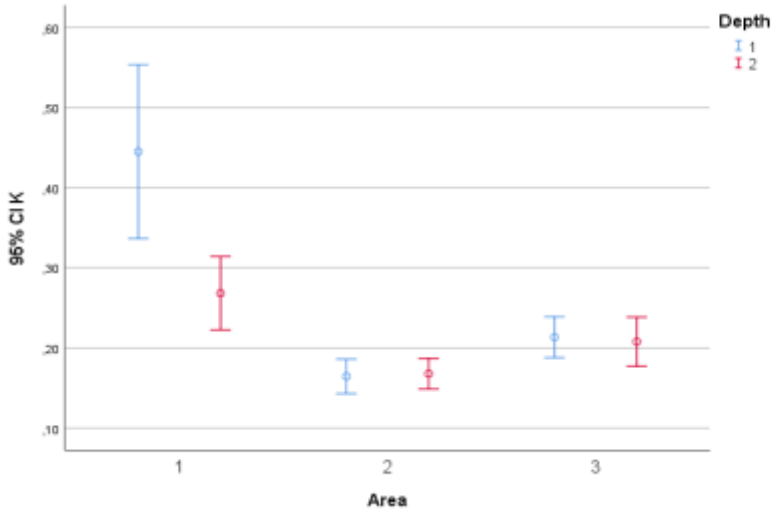

Figure 4. Mean and confidence interval 95% of soil exchangeable K ($cmol_c\ kg^{-1}$) for depths 1: 0-30 cm and 2: 30-60 cm, from areas: 1, 2 and 3.

Soil exchangeable K was found to be low, in both the upper and lower layers, in both fields in the upland (Areas 2 and 3) (Figure 4). The field in the lowland (Area 1) showed higher concentration of exchangeable K in the upper layer, compared to the other two fields. Even in this later case, however, the soil exchangeable K content was a little higher than low. Soil available (Olsen) P content was found to be low in Area 2 in both depths under investigation (Figure 5). Medium content of soil available P was found in the lower layer of Area 1, whereas in the upper layer

of Area 1 the soil available P content was high. In the case of Area 3, in the lower layer (30-60 cm), there was a trend for lower P concentration in the first sampling distance (0.5xCW), although the difference was not statistically significant. On average, soil available P in Area 3 was high.

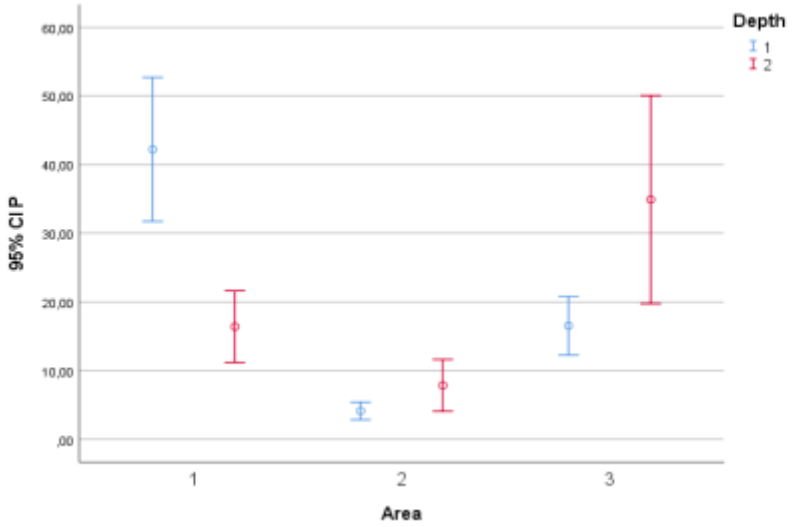

Figure 5. Mean and confidence interval 95% of soil available (Olsen) P (mg kg^{-1}) for depths 1: 0-30 cm and 2: 30-60 cm from areas: 1, 2 and 3.

CONCLUSION

Results showed that organic matter content, total N, available P and exchangeable K did not differ significantly with distance from the hedgerow trees row. Soil organic matter and total N were not evenly distributed through the soil profile. The largest organic matter and N pool occurred in the top 30 cm. This finding was particularly evident in the upland areas. The data provided evidence of C sequestration in the soils thus indicating significant environmental benefits. Soil exchangeable K was in general low. Soil available P content ranged from low to high, between the areas and sampling depths. The results favour the adoption of agroforestry in the plain area of Mouzaki, Greece; however detailed investigation to tree-specific effect of agroforestry on soil quality parameters is further needed.

ACKNOWLEDGEMENT

The present study is part of the project entitled “Perspective of Agroforestry in Thessaly region: A research on social, environmental and economic aspects to enhance farmer participation”. The project is funded by the General Secretariat for Research and Technology (GSRT) and the Hellenic Foundation for Research and Innovation (HFRI).

REFERENCES

Eichhorn M.P., Paris P., Herzog F., Incoll L.D., Liagre F., Mantzanas K., Mayus M., Moreno G., Papanastasis V.P., Pilbeam D.J., Pisanelli A. and Dupraz C. (2006) Silvoarable systems in Europe – past, present and future prospects. Agroforestry Systems, 67, 29-50.

FAO, Food and Agriculture Organization of the United Nations (2015) Agroforestry. http://www.fao.org/forestry/agroforestry/80338/en/ Accessed on 26/05/2020.

Gikas G. D., Tsihrintzis V. A. and Sykas D. (2016) Effect of trees on the reduction of nutrient concentration in the soils of cultivated areas. Environmental Monitoring and Assessment, 188(6), 327.

Horwath W.R. and Kuzyakov Y. (2018). The potential for soils to mitigate climate change through carbon sequestration. In: Climate change impacts on soil processes and ecosystem properties, Developments in Soil Science, 35, 61-92, Elsevier.

Jose S. (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems, 76, 1-10.

Nair P.K. (2011) Agroforestry systems and environmental quality: introduction. Journal of Environmental Quality, 40(3), 784-790.

Oelbermann M. and Voroney R. P. (2007) Carbon and nitrogen in a temperate agroforestry system: using stable isotopes as a tool to understand soil dynamics. Ecological Engineering, 29, 342-349.

Papanastasis V.P., Mantzanas K., Dini-Papanastasi O. and Ipsikoudis I. (2009) Traditional agroforestry systems and their evolution in Greece. In: Agroforestry in Europe: Current Status and Future Prospects, Eds: Rigueiro-Rodriguez A., McAdam J., Mosquera-Losada M.R., Springer, 89-109.

Ramesh T., Bolan N.S., Kirkham M.B., Wijesekara H., Kanchikerimath M., Rao C.S., Sandeep S., Rinklebe J., Ok Y.S., Chouhury B.U., Wang H., Tang C., Wang X., Song Z. and Freeman II O.W. (2019) Soil organic carbon dynamics: impact of land use changes and management practices: a review. Advances in Agronomy, 156, 1-107.

Schultz A. M., V. Papanastasis, T. Katelman, C. Tsiouvaras, S. Kandrelis and A. Nastis, 1987. Agroforestry in Greece. Working document. Laboratory of Range Science, Department of Range and Wildlife Science, Aristotle University of Thessaloniki.

Vrahnakis M.S., Fotiadis G., Pantera A., Papadopoulos A. and Papanastasis V.P. (2014). Floristic diversity of valonia oak silvopastoral woodlands in Greece. Agroforestry Systems, 88, 877-893.

Vrahnakis M., Nasiakou S., Kazoglou Y. and Blanas G. (2016) A conceptual business model for an agroforestry consulting company. Agroforestry Systems, 90, 219-236.

Original Scientific paper
10.7251/AGRENG2002114S
UDC 582.475(65)

TYPOLOGY, PRODUCTIVITY AND DYNAMICS OF ALEPPO PINE STANDS IN THE OUARSENIS MASSIF (ALGERIA)

Mohamed SARMOUM*[1], Rafael NAVARRO-CIRRILLO[2], Frederic GUIBAL[3], Fatiha ABDOUN[4]

[1]Laboratory of Plant Physiology and Out Soil Culture, Faculty of Natural and Life Sciences, Ibn Khaldoun Tiaret University, Algeria
[2]Department of Forest Engineering, Group of Evaluation and Restoration of Agricultural and Forestry Systems, Dendrodat Lab, University of Córdoba, Spain
[3]Mediterranean Institute of Biodiversity and Marine and Continental Ecology (IMBE), UMR 7263 CNRS-IRD, Aix-Marseille University (AMU), Aix-en-Provence, France
[4]Laboratory of Plant Ecology and Environment, Faculty of Biological Sciences, University of Science and Technology HouariBoumediene (USTHB), Algiers, Algeria
*Corresponding author: sarmoum.med82@gmail.com

ABSTRACT

Aleppo pine is the most important forest species in Algeria. This species has been used for a long time in reforestation programs, notably the "green dam" planted in the 1970s. Despite this importance, the Aleppo pine continues to undergo all kinds of degradation such as land clearing, illegal cutting and fire. This situation is causing reduction of potential wood production, also jeopardizing the vitality of the stands and their regeneration. This work aims to describe the typology, productivity and dynamics of Aleppo pine stands in the Ouarsenis massif (West of Algeria). 27 plots were installed to describe the stands (composition of forest species, dbh , total height, and basal area). Regeneration was estimated by the rate of juvenile individuals (dbh<5cm). The results obtained shows that the Aleppo pine develops different conditions for altitude, climate and type of soil. These conditions have a direct influence on the structure of the Aleppo pine and its productivity. The best populations develop on an average altitude (500 to 1400 m), in subhumid and semi-arid climates, on southern exposures and on limestone soils. The stands are mostly young (age <70 years) with good natural regeneration. These results put focus on the factors of degradation of the Aleppo pine, in particular the recurring fires and the lack of silvicultural management which application can improve the productivity and the vitality of the stands.

Keywords: *Aleppo pine, Ouarsenis massif, productivity, stands dynamic.*

INTRODUCTION

The Aleppo Pine (*Pinus halepenis* Mill) is one of the most characteristic species of the Mediterranean basin, particularly the western part (Quézel, 2000; de Luis et al., 2013), where it occurs both on the north and south shore of the Mediterranean

(Quézel and Médail, 2003). In Algeria, this species occupies an important place in the country's forest policy, both through its spontaneous presence in almost all of northern Algeria; except from the Numidian and Kabyle coastlines (Boudy, 1950; Kadik, 1987), and for its use for more than 50 years in reforestation programs (Bensaid, 1995). A hardy species that tolerates drought, this species is nevertheless very sensitive to forest fires which devastate tens of thousands of hectares each summer (Meddour-Sahar et al., 2008). This species has been the subject of several studies in Algeria, notably on the description of forest stands (Boudy, 1950); productivity (Kadik, 1987; Bentouati, 2006), dendroecology (Mederbel, 1992; Safar, 1994; Sarmoum et al., 2016) and phytosciology (Kadik, 2005).

This work is focused on the Ouarsenis massif (western Algeria), the choice of this area is dictated by the presence of several Aleppo pine stands which develop under variable ecological conditions. These stands have not been the subject of previous studies or silvicultural management. This work consists in (i) describing the current state of Aleppo pine stands in the Ouarsenis massif (ii) studying the long-term dynamics of tree growth (iii) studying the productivity of this species by depending on the environmental conditions.

MATERIALS AND METHODS

Description of the study area

The Ouarsenis massif is the most important forest massif in western Algeria. Several geological formations generating a variety of substrates and soils (Mattauer, 1958; Sari, 1977). The climate varies from semi-arid to humid with an altitudinal gradation ranging from 400m to 1985m. The Massif shelters several species and forest formations, among others, Atlas cedar (*Cedrus atlantica* (Endl.) Manetti ex Carrière)., Aleppo pine, holm and cork oaks (*Quercus ilex* L., *Q. suber* L.), Berber thuja (*Tetraclinis articulata* (Vahl) Masters) (Boudy, 1950). The pine forests occupy nearly 70% of the forest cover (BNEDER, 2009). Having been overexploited in the last century and suffered very severe fires, especially in 1893 and 1936 (Boudy, 1950) and others repeated in recent years, these formations are currently more or less degraded (BNEDER, 2009).

Sampling and data analysis

An stratified sampled based on altitude, slope, aspect, soil type and stand structure (age, density, anthropogenic disturbance… etc.) was conducted in the Ouarsenis massif between 2016 and 2018 (Gounot, 1969). A total of 9 sites each comprising three (3) rectangular plots of 0.1 ha (50 * 20 m) were set up (Tab.1). At the level of each plot, total and dominant height (e.g. the average height of the 100 largest stems in the stand), dbh and basal area of all the individuals of forest species with dbh>5 cm were measured. Frequency of forest species (%) and density were also estimated. The density of juvenile stages (5 cm<diameter <10 cm) was used to estimate the regeneration of forest species (Dobrowolska and Veblen, 2008).

The dendrometric data collected at the level of each plot were grouped by site to calculate the statistical parameters (mean, standard deviation) relating to each

variable studied. Post-hoc comparison of means was performed by Tukey's test after single-factor analysis of variance (ANOVA). For all statistical tests applied, the null hypothesis was rejected at the significance level of $P \leq 0.05$. Statistical processing was performed using SPSS 16.0 package.

Radial growth dynamic

From 15 dominant Aleppo pine individuals per plot, two cores at breast height were taken using a Suunto® increment borer, in a direction parallel to the contour lines, to study radial growth dynamics. The cores were mounted, sanded and polished; the crossdating was performed under a binocular microscope, following standard dendrochronological methods (Speer 2010). The ring width was measured to the nearest 0.01 mm using a LINTAB measuring device and the Time Series Analysis Program (TSAP). Two chronologies were created and the trend due to the geometrical constraint of adding a volume of wood to a stem of increasing radius was correctedby converting tree-ring widths into basal area increments (BAI) using the formula: $BAI= \pi(Rt2 – Rt-12)$ where R is the radius of the tree and t is the year oftree-ring formation using the 3pBase program. Cumulative growth curves for each series were established to study the effect of environmental conditions on the productivity of each site.

Table 1. Description of the ecological stations sampled in the study area.

Station	Altitude (m)	Exposure	Slope (%)	Soil	Coverage Global (%)
PIN1	1225	NNE	30-40	Sandstone colluvium	60%
PIN2	1041	NW	40-50	Sandstone colluvium	70%
PIN3	1143	NW	30-40	Sandstone colluvium	80%
PIN4	1150	NNE	10-20	Limestone	60%
PIN5	1254	NW	20-30	Limestone	70%
PIN6	508	SW	30-40	Schist	60%
PIN7	815	SW	20-30	Limestone	60%
PIN8	1030	SE	30-40	Limestone	80%
PIN9	1320	SE	40-50	Limestone	80%

RESULTS AND DISCUSSION

Age

Studied Aleppo pine populations have a mean age ranging from 43 years (PIN7) to 112 years (PIN6) (Table 2). We can therefore distinguish older populations (> 100 years): PIN5 and PIN6; moderately old (50-100 years) which are the PIN1, PIN2, PIN3, PIN4 and PIN9 populations and young populations (<50 years) which are the PIN7 and PIN8 populations.

Composition in forest species

Aleppo pine is found in its pure (PIN6 and PIN7) or mixed stands with holm oak and cade juniper (*Juniperus oxycedrus* Sibth. & Sm.) (PIN1, PIN2, PIN3, PIN8 and PIN9) and with Atlas cedar (PIN4 and PIN5) (Table 2), ranging its proportions from 100% to 36%. Pure stands are more frequently localized at low altitudes (<1200 m), increasing the presence of holm oak (southern aspect) and Atlas cedar (northern aspect) at higher altitudes.

Structure and regeneration

Aleppo pine density ranged from 110 (PIN6) to 790 trees ha^{-1} (PIN7) (Table 2). Three types of stands according to density can be described: low density (≤ 300 trees ha^{-1}, PIN2, PIN3, PIN4 and PIN6), medium density (300-500 trees ha^{-1}, PIN1 and PIN9), high density stands (> 500 trees ha^{-1}, PIN5, PIN7 and PIN8).

Regarding the regeneration density, it ranged between 30 trees ha^{-1} (PIN2 and PIN4) to 100 trees ha^{-1} (PIN7). We also noted the total absence of Aleppo pine regeneration for the PIN4 and PIN9 sites, where high values of Atlas cedar and holm oak regeneration was found (Table 2).

Height and diameter

Minimum total and dominant heights were found at the PIN3 and maximum at the PIN4 station, with significant differences ($F=9.81$; $P<0.001$) among height groups (Table 2). This discrimination highlights the effect of environmental factors on the total height. The highest values were located on limestone on the northern slope (PIN4, PIN5). On the other hand, the lowest values were recorded on a sandstone substrate (PIN1, PIN2 and PIN3).

Mean diameter ranged from 13.86 cm (PIN7) to 49.56 cm (PIN4), distinguishing six significant groups ($F = 18.00$; $P<0.001$): group a (PIN7), group ab (PIN1 and PIN8), group b (PIN2), group bc (PIN3 and PIN5) , group cd (PIN9) and group d (PIN4). This was related to the basal area which ranged from 11.19 $m^2 h^{-1}$ (PIN1) to 52.9 $m^2 h^{-1}$ (PIN5). The most productive stations were located on limestone substrate (PIN5 and PIN9) and/or in low-sloping land (PIN4) and less productive on sandstone substrate (PIN1, PIN2 and PIN3) (Table 2).

Radial growth dynamic

Mean annual growth (MG) ranged from a minimum value of 1.98 mm $year^{-1}$ (PIN5) to a maximum value of 3.95 mm $year^{-1}$ (PIN7). Comparison of the MG values with other Mediterranean pine forests shows values that are clearly higher than those obtained in the Saharan Atlas (Safar, 1994), rather high than those of Orania (Mederbal, 1992) or even the south from France (Nicault, 1999), but

corroborate with those obtained in Greece (Papadopoulos, 1992) and Tunisia (El Khorchani et al., 2007).

The values of the standard deviation (SD) show a strong interannual variability of the radial growth due to the fluctuations of the random factors which act on the radial growth (climate, thinning, attack of parasites), but also the effect of the age. In fact, older populations (PIN5 and PIN6) exhibit greater fluctuations than younger populations (PIN7 and PIN8). The highest MG values were obtained in young populations (PIN7 and PIN8), which is in concordance with previous studies showing that the Aleppo pine reaches its maximum productivity at the age of 70 years; beyond this age its productivity begins to decline (Bentouati, 2006; Vennetier et al., 2010).

The spatio-temporal variations of the ring surfaces of Aleppo pine populations (Fig. 1) show linear profiles for most populations (except for PIN2 and PIN3). The high and medium frequency variations are expressed by periods of rapid annual increases following by decreases. These variations were analogous to those observed for radial growth, but they show quite different long-term variations (low frequency variations), in that there is an increase in basal area over time, as we excepted for the PIN2 and PIN3 populations.

Populations of the Aleppo pine showed very marked differences in production (Fig. 2). At approximately the same age, populations do not exhibit the same ability to grow, so site factors seem to play an important role on population growth. Indeed, at a common age of 40 years, the PIN4 and PIN2 populations were more productive, the PIN3, PIN9, PIN1 and PIN6 populations were moderately productive and finally, the PIN7, PIN8 and PIN9 populations showed weak production. The latter, because of their young age, also present linear profiles indicating a low silvicultural intervention. The PIN2 and PIN4 populations showed an exponential growth profile which attests to the good conditions for tree growth apart from environmental disturbances. The PIN6 population showed a spectacular increase in productivity in the 1950s and 1970s. This singularity cannot be explained by the single climatic variable which acts homogeneously on the populations of the same region, but by the anthropogenic factors (cutting, and thinning) which promoted the growth of certain trees in the population. On the other hand, the other populations (PIN1, PIN3 and PIN5) started to show a change in trend from the 1980s.

Table 2. Structure and dendrometric parameters of Aleppo pine stands in the study area. The different letters indicate the post-hoc comparison (Tukey test). Hd: Dominant height, Ca: *Cedrus atlantica*, Qi: *Quercus ilex*, Ph: *Pinus halepensis*, Jo: *Juniperus oxycedrus*.

Sites	Composition (%)	Total density (ha^{-1})	Density of juvenile stages (ha^{-1})	Total hight (Hd) m (m)	Diameter (cm)	Basal area ($m^2.ha^{-1}$)
PIN1 **Total**	Ph (87,5) Qi (12,5)	280,3 40,3 320,6	30 10 40	7,15 ± 2,17 (9,1) ab 3,32 ± 0,92	20,23±9,14 ab 11,54±1,53	10,77 0,42 11,19
PIN2 **Total**	Ph (87) Qi (13)	260 40 300	20 10 30	6,77±2,80 (9,4) ab 2,92±0,95	30,35±15,82 b 10,66±2,08	23,7 0,4 24,1
PIN3 **Total**	Ph (73) Qi (24) Jo (3)	220 70 10 300	10 30 0 40	6,05±2,42 (8,1) a 2,11±0,86 3,5±0,7	33,81±19,04 bc 9,55±5,11 11,46±3,2	25,7 0,6 0,1 26,4
PIN4 **Total**	Ph (55) Ca (28) Jo (17)	160 80 50 290	0 20 10 30	15,76± 8,71 (21,3) d 2,01± 0,27 1,78± 0,53	49,56± 23,02 d 3,14±1,8 06,05±3,41	37 0,2 0,1 37,3
PIN5 **Total**	Ph (55) Ca (27) Qi (07) Jo (11)	310 150 40 60 560	30 30 20 10 90	11,87± 7,32 (19,7) cd 7,64± 5,22 3,37± 1,63 1,61± 0,45	33,13± 19,04 bc 25,15±23,34 5,25±2,37 03,18±1,96	39,26 13,44 0,1 0,1 52,9
PIN6 ***Total***	Pa (100)	110 110	10 10	10,90±6,81 (14,6) bc	49,39±30,13 d	28,19 28,19
PIN7 **Total**	Ph (100)	790 790	100 100	8,29±3,5 (11,60) abc	13,86±5,60 a	13,8 13,8

PIN8 **Total**	Ph (70,3) Qi (20,3) Jo (9,4)	450 120 20 590	10 50 10 70	7,76±2,26 (10,8) abc 2,65±1,86 2,05±0,5	24,7±10,69 ab 5,16±3,9 5±0,7	25 0,3 0,1 25,4
PIN9 **Total**	Ph (36) Qi (34) Jo (30)	160 150 130 440	0 50 40 90	10,12±5,41(12,3) abc 3,33±1,57 2,15±0,72	48,23±30,40 cd 13,43±4,8 13,22±6,13	32,45 2,87 2,74 38,06

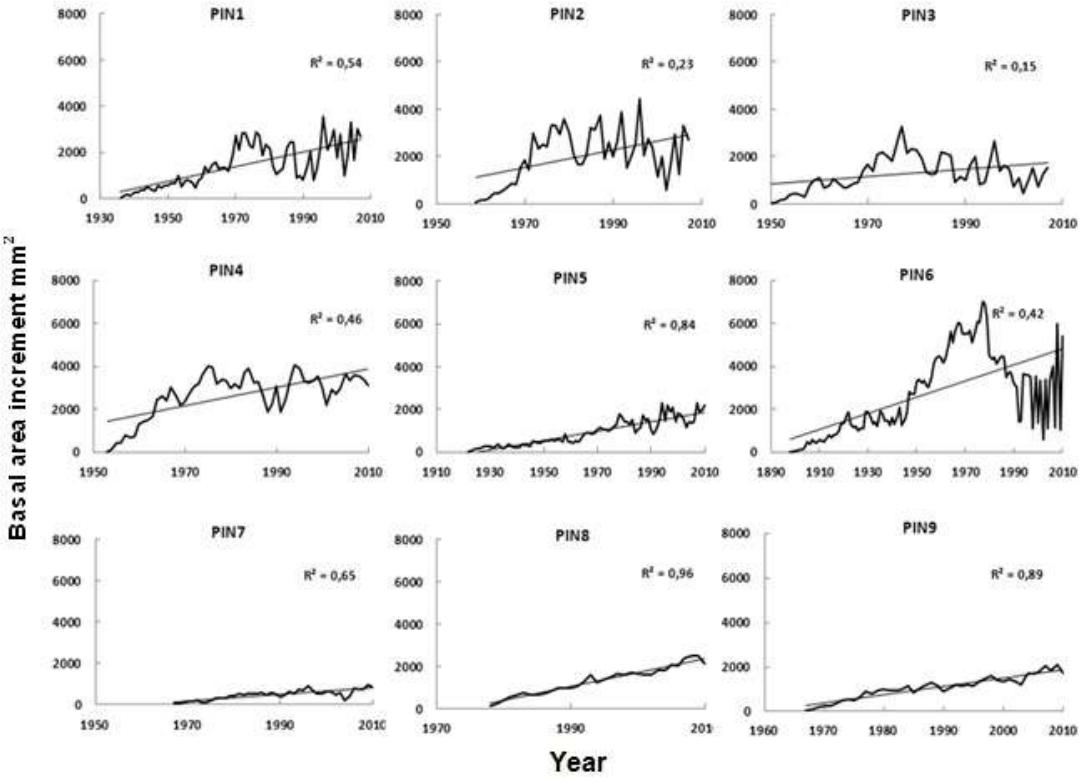

Figure 1. Curves of annual growth ring area in Aleppo pine.

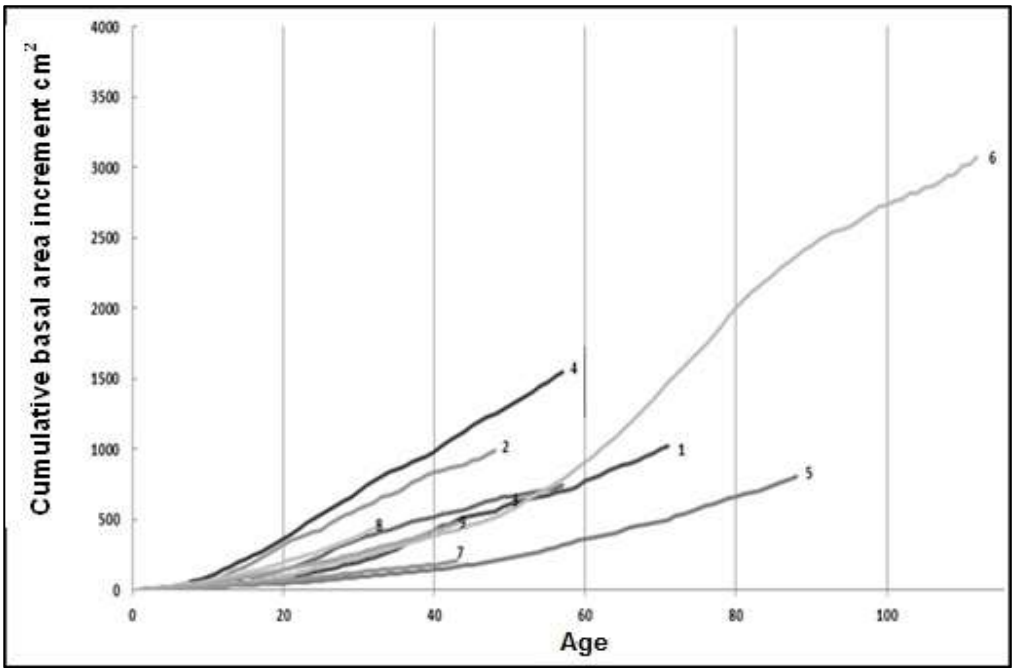

Figure 2. Curves of annual cumulative growth areas of tree rings as a function of age in Aleppo pine

CONCLUSION

This work shows a current and retrospective assessment of the Aleppo pine stands in the Ouarsenis massif (Algeria). The results obtained show a close relationship between the dendrometric and dendroecological parameters and the environmental conditions. The latter also intervene to explain the structure of stands and their productivity. As a result, the best stands develop on a limestone substrate, in southern exposures and in medium altitudes. Human action can also modify these parameters. Silvicultural intervention sometimes seems necessary to improve the health status of the stands, promote their regeneration and productivity and reduce the frequency of fires.

ACKNOWLEDGEMENTS

This work was funded through the PNR project (DGRSDT, Algerian Ministry of Higher Education and Scientific Research). The authors thank the Algerian Ministry of Agriculture and Directorate General of Forests for the permission to work in the National Park of Theniet El Had. We also acknowledge the institutional support of the University of Cordoba-Campus de Excelencia CEIA3 and ESPECTRAMED (CGL2017-86161-R) project.

REFERENCES

Bensaid S., 1995. Bilan critique du barrage vert en Algérie (Critical assessment of the "green dam" in Algeria). Sécheresse, 6 (3): 247-255.

Bentouati A., 2006. Croissance, productivité et aménagement des forêts de Pin d'Alep (Pinus halepensis) du massif d'Ouled yagoub (Khenchela –Aures) (Growth, productivity and management of Aleppo pine (Pinus halepensis) forests in the Ouled yagoub massif (Khenchela –Aures). Thèse doctorat en sciences Agronomiques, université de Batna, 115 p.

BNEDER, 2009. Plan national de développement forestier (PNDF) (National Forest Development Plan). Rapport de synthèse nationale. Alger, Algérie, 87p.

Boudy P., 1950. Economie forestière Nord-africaine, monographies et traitements des essences forestières (North African forest economy, monographs and treatments of forest species). Larousse, Paris, 523p.

de Luis M., Cufar K., Di Filippo A., Novak K., Papadopoulos A., et al., 2013. Plasticity in Dendroclimatic Response across the Distribution Range of Aleppo Pine (Pinus halepensis). Plos one, 8(12): e83550. doi:10.1371/journal.pone.0083550.

Dobrowolska D., Veblen T., 2008. Tree fall-gap structure and regeneration in mixed Abies alba stands in central Poland. Forest Ecology and Management 255: 3469-3476.

El Khorchani A., Gadbin-Henry C., Khaldi A., 2007. Impact de la sécheresse sur la croissance de trois espèces forestières en Tunisie (Pinus halepensis Mill., Pinus pinea L. et Pinus pinaster Sol.) (Impact of drought on the growth of three forest species in Tunisia (Pinus halepensis Mill., Pinus pinea L. and Pinus pinaster Sol.). Sécheresse, 18 (02): 113-121.

Gounot M., 1969. Méthodes d'étude quantitative de la végétation (Methods for the quantitative study of vegetation). Masson & cie, Paris, 314p.

Kadik B., 1987. Contribution à l'étude du Pin d'Alep (Pinus halepensis Mill.) en Algérie. Écologie, dendrométrie, morphologie (Contribution to the study of the Aleppo pine (Pinus halepensis Mill.) In Algeria. Ecology, dendrometry, morphology). O.P.U, Alger, 623p.

Kadik-Achoubi L., 2005. Phytosociologie et phytoécologie des formations à pin d'Alep dans les monts de Senalba (Djelfa, Algérie) (Phytosociology and phytoecology of Aleppo pine formations in the Senalba mountains (Djelfa, Algeria). Doctoral thesis, USTHB, 500p.

Mattauer M., 1958. Etude géologique de l'Ouarsenis oriental (Algérie). Service de la Carte Géologique de l'Algérie (Geological study of the eastern Ouarsenis (Algeria). Service of the Geological Map of Algeria, Algiers, 550p.

Mederbal K., 1992. Compréhension des mécanismes de transformation du tapis végétal: Approches phytoécologiques par télédétection aérospatiale et analyse dendroécoloqique de Pinus halepensis Mill., dans l'ouest Algérien (Understanding of the transformation mechanisms of the plant cover: Phytoecological approaches by aerospace remote sensing and dendroecological

analysis of Pinus halepensis Mill., In western Algeria). Doctoral thesis, University of Aix-Marseille III, 229p.

Meddour-Sahar O., Meddour R., Derridj A., 2008. Analyse des feux de forêts en Algérie sur le temps long (1876-2007) (Analysis of forest fires in Algeria over the long term (1876-2007)). Option méditerranéenne 39 : 1-11.

Nicault A., 1999. Analyse de l'influence du climat sur les variations inter et intra-annuelles de la croissance radiale du pin d'Alep (*Pinus halepensis* Mill.) en Provence calcaire (Analysis of the influence of the climate on the inter and intra-annual variations in the radial growth of the Aleppo pine (*Pinus halepensis* Mill.) In limestone Provence). Doctoral thesis, University of Aix-Marseille III, France, 256p.

Papadopoulos A., 1992. Contribution à l'étude écologique et dendroclimatologique du pin d'Alep (Pinus halepensis Mill.) en Grèce (Contribution to the ecological and dendroclimatological study of the Aleppo pine (Pinus halepensis Mill.) In Greece). Doctoral thesis, University of Aix Marseille III, 189p.

Quézel P., 2000. Réflexions sur l'évolution de la flore et de la végétation au Maghreb méditerranéen (Reflections on the evolution of flora and vegetation in the Mediterranean Maghreb). Ibis, Paris,117p.

Quézel P., Médail F., 2003. Ecologie et biogéographie des forêts du bassin méditerranéen (Ecology and biogeography of the forests of the Mediterranean basin). Lavoisier, Paris, 576p.

Safar W., 1994. Contribution à l'étude dendroécologique du pin d'Alep (Pinus halepensis Mill.) dans une région semi-aride de l'Algérie : l'Atlas Saharien (Ouled Nail- Aurès- Hodna) (Contribution to the dendroecological study of the Aleppo pine (Pinus halepensis Mill.) In a semi-arid region of Algeria: the Saharan Atlas (Ouled Nail-Aurès-Hodna). Doctoral thesis, University of Aix-Marseille III, France, 225p.

Sari Dj., 1977. L'Homme et l'érosion dans l'Ouarsenis (Man and Erosion in Ouarsenis). SNED, Algiers, 546p.

Vennetier M., Ripert C., Brochiéro F., Rathgeber C., Chandrioux O., Estève R., 2010. Évaluation de la croissance du Pin d'Alep en région méditerranéenne française (Assessment of Aleppo Pine growth in the French Mediterranean region). Revue Forestière Française 5: 11-17.

Original Scientific paper
10.7251/AGRENG2002124A
UDC 551.583:63(611)

DETERMINANTS AND STRATEGIES OF FARMERS' ADAPTATION TO CLIMATE CHANGE: THE CASE OF MEDENINE GOVERNORATE, TUNISIA

Fatma ARIBI[1,2]*, Mongi SGHAIER[1]

[1]Institute of Arid Regions of Medenine, Laboratory of Economy and Rural Societies, Medenine, Tunisia
[2]National Agronomic Institute of Tunis, Department of Agricultural and Agri-food Economy, Tunisia
*Corresponding author: fatmaribi@gmail.com

ABSTRACT

Climate change is a worldwide environmental issue to all economic sectors, mainly the agricultural sector. Tunisia is one of the countries adversely affected by climate change because of its low adaptive capacity. Adapting to climate threat is the main goal of farmers, who are the primary stakeholders in agriculture, to increase the resilience of their farming systems. Based on a survey between March and May 2018 with 100 agricultural households from the governorate of Medenine, which belongs to Southeast Tunisia, this paper examined the main adaptive measures to climate change used by farmers, the factors influencing their choice of measures and the constraints to adaptation. To explore the factors affecting the choice of adaptive measures, this study employed a multinomial logit regression. Results showed that irrigation, crop diversification, integration of crop with livestock and shifting from farm to non-farm activities were the main adaptive measures implemented by farmers in the study area. Further, the multinomial logit model indicated that the factors influencing the choice of adaptive measures included household head age, access to extension services, household income, number of years of experience of the household head in agriculture, and the distance to the market. The results demonstrated also that adaptation to climate change was hindered by many factors such as constrained resources, lack of money, and water shortage. The findings of this research suggest the need for improving the access to extension services, to water, and to means of production to enhance the resilience of vulnerable agricultural households and to improve their wellbeing.

Keywords: *Climate change, adaptive measures, agricultural households, multinomial logit regression, governorate of Medenine.*

INTRODUCTION

Currently, climate change is at the center of concerns of both scientific actors and political decision-makers. Climate change poses an increasingly discernible threat to the viability of in developing countries. It has a direct impact on agricultural

production, since farming systems are climate dependent (Belay et al., 2017). In fact, the conditions of agricultural production have become more and more difficult (Brunette et al., 2018). This impact is particularly significant in developing countries where agriculture constitutes the main source of employment and income for the majority of the population. Furthermore, the social construct and the economic constraints that underlie inequalities in access to productive resources are reinforced by climate change (Hisali et al., 2011).

Agriculture is an important sector of the Tunisian economy. It contributes about 10 % of the GDP and employs about 18 % of the active population. Despite its significant contribution to the entire economy, this sector is challenged by the negative effects of climate change. Its influences are manifested by droughts and lack of rainfall, heat waves and low productivity. In such context, and to ensure the viability of farming systems and income stability of farm households, adaptation measures are today the only alternatives to reduce the effects of climatic uncertainties. Adaptation to climate change refers to "*strategies, initiatives, and measures aimed at reducing the vulnerability of natural and human systems to the current and expected effects of climate change, which mitigates damage or values the benefits*" (IPCC, 2001). Understanding the adaptive measures choices improves policies focused toward tackling the issues that climate change is imposing to farmers. Moreover, for any adaptive measure several socio-economic, environmental, and institutional factors may drive its employment. The examination of these factors is crucial for policy makers to improve the farmers' adaptive capacity.

Although internationally extensive studies on agricultural households adaptation to climate change, limited researches have been performed so far in Tunisia. In fact, a considerable number of researches have investigated farm-level adaptation in different countries and have attempted to explore farmer's adaptive measures choices as well as their determinants (Belay et al., 2017; Deressa et al., 2009; Hassan and Nhemachena, 2008; Hisali et al., 2011; Shikuku et al., 2017). Up to date researches on climate change and agriculture in Tunisia have been limited to impacts of climate change on agricultural production. A very few number of studies have considered farmers' climate change adaptation. Therefore, the aim of this study is to fill this research gap with regard to adaptation to climate change in the agricultural sector. This paper seeks to answer the three following research questions: What are the major adaptive measures employed by farm households? What are the factors influencing these adaptive measures? What are the main barriers to adaptation?

MATERIAL AND METHODS

The study was carried out in Medenine governorate, which belongs to Southeast Tunisa (Figure 1). Medenine governorate, characterized by an arid climate, is considered one of the most vulnerable governorates to the impacts of climate change due to high temperatures and low rainfall (Sghaier and Ouessar, 2013).

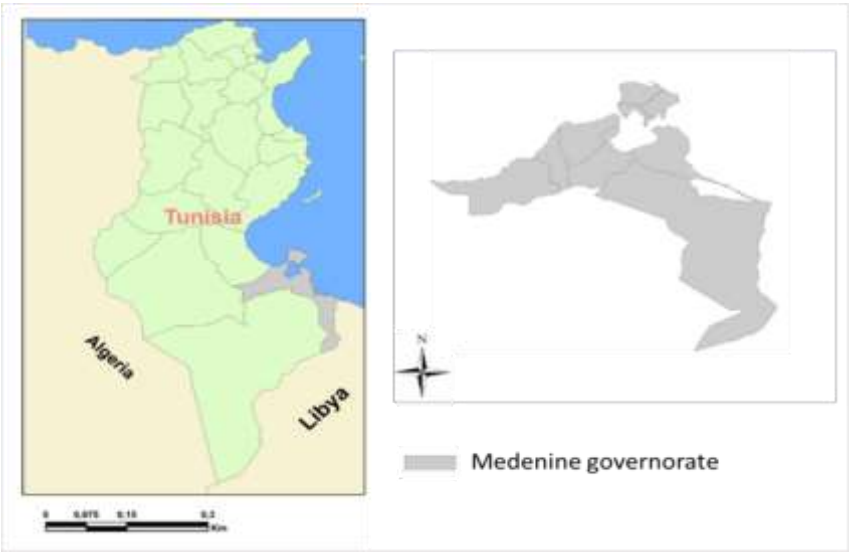

Figure 1. Geographical location of Medenine governorate
*Source: Own elaboration

The data was collected through a questionnaire survey during the period March-May 2018 from 100 agricultural households that represent the main production systems in the governorate of Medenine. A structured questionnaire was designed to collect information on socio-demographic characteristics of farmers, their farming systems, their incomes, their relation with institutions, and their main adaptive options. To answer our research questions, our analyses were performed using three steps, following a progressive approach: In a first step, we carried out a descriptive statistics to explore the main adaptive measures employed by the surveyed farmers. In a second step, to analyze the determinants of farmers' adaptation choices, we used a multinomial logit model (MNL). This model is widely used in adoption decision researches involving multiple choices (Alam et al., 2016; Deressa et al., 2009; Hisali et al., 2011). It has two main advantages: firstly, it allows the analysis of decisions for more than two options (Hassan and Nhemachena, 2008); secondly, its estimation and interpretation are simple. An important condition that must be satisfied in MNL regression is the assumption of Independence of Irrelevant Alternatives (IIA); it indicates that the probability of adopting a specific adaptation strategy by a given farmer requires independence from the probability of selecting another adaptation strategy (Alam et al., 2016). To resolve this problem we have considered the most preferred adaptation measure for each farmer. For our study, the adaptation measures are five: diversifying income sources, integrating crop with livestock, crop diversification, irrigation and non adaptation. In the MNL, a baseline alternative must be chosen because the option should always be in the interviewees' choice (Sadiq et al., 2019). The option "no adaptation" was considered as the baseline and was compared with other

adaptation strategies. The form of the MNL model is specified in the following equation:

$$\textbf{Prob}\ (A_i = j) = e^{\beta' j} X_i \quad / \sum_{k=0}^{k=j} e^{\beta' k} X_i \qquad (1)$$

Where A_i is the probability of farm household i to choose option j, j indicates the adaptation strategies (Table 1), β is a vector of coefficients for each of the independent variables Xi, k represents the "no adaptation" choice that was used as the base option, and Xi represents the independent variables. The independent variables were chosen based on a literature review (Deressa et al., 2009; Sadiq et al., 2019; Shikuku et al., 2017) and our previous experience in the field.

In a third step, this study investigates the declared constraints that prevent farmers to successfully employ their adaptive strategies.

RESULTS AND DISCUSSION

The results of our study revealed that agricultural households are adopting different adaptive measures to face climate change. Farmers were asked about their preferred adaptive measure. The results reported by the surveyed farmers are shown in figure 2. Our findings revealed that the most important adaptive measure employed by farmers in the study area is crop diversification followed by the integration of crops with livestock, the diversification of income sources, and irrigation. The MNL regression was used to explore farm households' choices of adaptive options to reduce the effects of climate change. In our analysis, we employed "no adaptation" option as a baseline category and estimated the other options as its alternatives. The likelihood ratio specified by the Chi-square test is significant as shown in Table 1. Our findings showed that the IIA assumption was respected. Therefore, the use of MNL model is appropriate to examine the determinants of adaptation options employed by farmers.

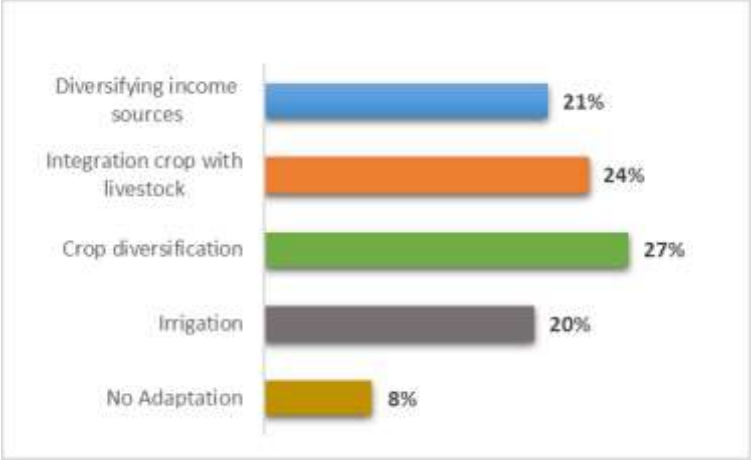

Figure 2. Main adaptation options to climate change and the proportion of respondents that practiced them.

The coefficient of MNL model gives only the direction of the effect of the independent variables on the dependent variable: estimations do not assess the magnitude of change. Therefore, in our analysis, we used odds-ratio for a simple and intuitive interpretation of coefficients. The following analysis presents and discusses the results of explanatory variables (Table 1).

The age of household head represents the experience, which may affect the adaptation to climate change. The household heads' age was a significant positive factor to crop diversification and to the integration of crop with livestock. It may be because skilled farmers have a better understanding of climate uncertainties. In those cases, the odds ratio of age variable are greater than one, this indicates that an increase of one year in the household head age will lead to 6 % increase in the odds of using crop diversification and 4 % in the integration of crops with livestock. Moreover, the access to extension services has a positively significant relationship with crop diversification; however, its relationship with the diversification of income sources is negative. This result is expected because extension advice is used to encourage farmers to diversify their crops. Therefore, this choice hurdles the ability of household members to undertake off-farm work, as more labor is required at the farm-level. As for odds ratio, an additional intervention from extension services will increase the practice of crop diversification by 33%, and decrease the probability of undertaking off-farm work (by 33%) as its odds ratio is less than one. Besides, the study revealed a significantly positive relationship of the experience of household head in agriculture with crop diversification and irrigation. This result supports previous evidence showing that farmers with high experience level were more likely to adapt to climate change (Deressa et al., 2009). A household head with an additional year of experience in agriculture is more likely to engage in crop diversification and irrigation, 12% and 14% respectively. In addition, the household income has a positively significant relation with the use of irrigation, the crop diversification and the integration of crops with livestock. Thereby, financial resources are required to adapt to climate change effects especially when it comes to expensive choices like irrigation and crop diversification. This result confirms previous studies, which found a positive relationship between household income and adaptation (Alam et al., 2016). With regard to odds ratio, increasing one unit in household income leads to an increase of the probability of employing irrigation and crop diversification by 2% and 3%, respectively. The distance to the market was found to be significant to explain farmers' adaptive choices (crop diversification and integration of crop with livestock). This factor acts as a proxy for the availability of input and the marketing of agricultural products. Increasing the distance to the market by one unit, leads to the decrease of probability of employing crop diversification and the integration of crop with livestock by 4% and 2% respectively.

Table 1. Predictability of the Multinomial Logit model

Explanatory Variable	Adaptation choices (dependent variable)							
	Irrigation		Crop diversification		Integrating crop with livestock		Diversifying income sources	
	Coef.	Odds-ratio	Coef.	Odds-ratio	Coef.	Odds-ratio	Coef.	Odds-ratio
Intercept	1.760		0.459		4.138		-0.11	
Age [Years]	0.95	1.38	**1.06***	1.330	**2.04****	1.113	3.93	1.020
Household size [Number]	1.649	5.202	5.249	190.440	4.615	100.963	0.497	1.644
Number of years of education of HH [Years]	0.48	1.12	1.01	1.14	-1.329	0.265	-0.58	0.555
Trainings [Number]	2.313	10.105	-0.422	0.656	1.082	2.950	2.511	12.319
Years of experience of HH [Years]	**1.31****	3.709	**1.386***	3.997	3.198	24.487	4.833	125.526
Herd size [Livestock Unit]	-2.290	0.101	-2.476	0.084	-4.307	0.013	-2.38	0.092
Agricultural area [ha]	0.579	1.784	0.292	1.339	-0.917	0.400	1.010	2.745
Irrigated area [ha]	-1.385	0.250	3.964	52.665	0.328	1.388	-4.47	0.011
Access to extension services	-6.688	0.001	**1.83****	1.33	-3.499	0.030	**-0.2***	0.779
Crop diversity index [Index]	-3.091	0.045	-2.334	0.097	-3.987	0.019	-2.23	0.107
Membership in any organization	-0.956	0.384	1.424	4.152	-0.888	0.411	-1.09	0.334
Household income [Local currency]	**2.012***	1.02	**2.060****	1.27	**1.03***	1.54	8.4	0.428
Subsidies [Local currency]	1.778	5.920	-5.534	0.004	-1.369	0.254	4.705	110.482
Distance to the market [Km]	3.58	36.161	**-4.20****	0.96	**-0.1****	0.98	3.054	21.193
Agricultural equipment [Local currency]	2.750	15.640	-0.936	0.392	-0.285	0.752	3.779	43.769

Base category : No adaptation
Number of observations : 100
LR chi^2: 90.8 **
Log likelihood : - 218.66 **
Pseudo R^2: 0.29

*** p < 0.1 ; ** p < 0.05 ; *** p < 0.001**

HH: Household

Turning now to the analysis of constraints that hurdle farmers to employ adaptive measures to mitigate climate change effects, despite the fact that farmers are trying to adapt their farming systems to climate change, they mentioned that there are many constraints that hurdle their adaptive choices. The main constraints declared by farmers include the lack of money, resource constraints, lack of information, shortage of water, and others… Lack of money hindered agricultural households from obtaining crucial inputs (purchasing seeds, irrigation facilities and fertilizers) they may need to adapt their practices to suit the climate change conditions. Although irrigation is used by some farmers, its extent is still limited. This deals with the failure of agricultural households to use groundwater because of the shortage of financial and technological capacity. The lack of information is associated with limited access by farmers to extension services in order to modify their agricultural practices in case of high temperature and prolonged drought. Moreover, farmers cited that the unavailability of resources at the farm level hurdle their capacity to adapt to climate change. Resources may include agricultural equipment, irrigation facilities, wells, means of transport, etc.

CONCLUSION

This study analyzed the adaptive choices made by farmers of Medenine governorate (Tunisian Southeast). The results showed that farmers are using different adaptive options to counter the adverse effects of climate change. The main practices and measures are grouped into five adaptation options: diversifying income sources, integrating crop with livestock, crop diversification, irrigation and non adaptation. A Multinomial Logit Model was used to examine factors affecting farmers' climate change adaptive choices. The logit model indicated that the factors influencing the choice of adaptive measures included household head age, access to extension services, household income, number of years of experience of the household head in agriculture, and the distance to the market. However, the farmers' capacity to adapt was hindered by several constraints: the lack of money, resource constraints, lack of information, shortage of water.

Our findings have several policy implication. The findings imply that improving the access to extension services, to water, to climate information and to means of production might enhance the resilience of vulnerable farm households. This involves the need to support the farmers' adaptive choices with a wide range of policy, technology, and institutional support.

REFERENCES

Alam G., Alam K., Mushtaq S. (2016). Influence of institutional access and social capital on adaptation decision: Empirical evidence from hazard-prone rural households in Bangladesh. Ecological Economics, Vol. 130, pp. 43–251.

Belay A., Recha W., Woldeamanuel T., Morton F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agriculture & Food Security, Vol. 6, pp 24-31.

Brunette M., Bourke R., Hanewinkel M., Yousefpour R. (2018). Adaptation to climate change in forestry: A multiple correspondence analysis (MCA). Forests Vol (9), pp. 20-29.

Deressa T., Hassan R.M., Ringler C., Alemu T., Yesuf M., (2009). Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global environmental change, Vol. 19, pp 248–255.

Hassan R.M., Nhemachena C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. African Journal of Agricultural and Resource Economics, Vol. 2, pp 83–104.

Hisali E., Birungi P., Buyinza F. (2011). Adaptation to climate change in Uganda: evidence from micro level data. Global environmental change, Vol. 21, pp 1245–1261.

IPCC. (2001). Climate change 2001: Synthesis report. Contribution of working groups I, II and III to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK.

Sadiq A., Kuwornu K., Al-Hassan R.M., Alhassan S.I. (2019). Assessing maize farmers' adaptation strategies to climate change and variability in Ghana. Agriculture, Vol. 9, pp 90-99.

Sghaier M., Ouessar M. (2013). L'oliveraie tunisienne face au changement climatique : Méthode d'analyse et étude de cas pour le gouvernorat de Médenine. Arid Regions Institute of Medenine, Tunis.

Shikuku M., Winowiecki L., Twyman J., Eitzinger A., Perez J.G., Mwongera C., Läderach P. (2017). Smallholder farmers' attitudes and determinants of adaptation to climate risks in East Africa. Climate Risk Management, Vol. 16. pp 234–245.

Original Scientific paper
10.7251/AGRENG2002132W
UDC 338.43:378.4(475)

COOPERATION OF AGRI-FOOD CLUSTERS WITH UNIVERSITIES: THE CASE STUDY FOR POLAND

Joanna WIŚNIEWSKA-PALUSZAK[1]*, Krzysztof KOSZELA[2], Izabela LIPIŃSKA[3], Lucyna PRZEZBÓRSKA-SKOBIEJ[4], Anna WIELICKA-REGULSKA[4], Arkadiusz SADOWSKI[4], Olga GRABOWSKA-CHENCZKE[5]

[1]Department of Economics, Poznan University of Life Sciences, Poland
[2]Institute of Biosystems Engineering, Poznan University of Life Sciences, Poland
[3]Department of Law and Organization of Agribusiness Enterprises, Poznan University of Life Sciences, Poland
[4]Department of Economics and Economic Policy in Agribusiness, Poznan University of Life Sciences, Poland
[5]Department of Social Sciences and Pedagogy, Poznan University of Life Sciences, Poland
* Corresponding author: joanna.wisniewska-paluszak@up.poznan.pl

ABSTRACT

Poland is a major supplier of food for Western Europe. It ranks 4th in the EU in arable land. Agri-food industry clusters are developing dynamically in Poland, which is mainly related to the agri-food specialisation of most regions of the country. Clusters play a significant role in creating supply chains, joint investments, and developing innovative solutions; for these reasons, their development depends on cooperative relations with scientific institutions, which become initiators of joint activities. This paper aims to investigate collaborative relationships that arise between agri-food clusters and universities. The article analyses an example of an agri-food cluster from the Greater Poland region, which mainly develops modern distribution channels of food products produced by its participants. To obtain data, we interviewed cluster management. We elaborate on the concept of university-cluster collaboration (UCC) which identifies that the cooperation between cluster participants and the universities bases on creating interpersonal relations by direct and personal interactions between cluster entrepreneurs and university research staff.

Keywords: *University-Cluster Collaboration (UCC), Cluster Initiative Centre, Agri-food Industry Cluster.*

INTRODUCTION

The competitiveness of the Polish agri-food sector may result from different factors, including the support for the development of clusters which play an increasingly significant role in creating supply and value chains, R&D, relational investments and open innovations (Wiśniewska-Paluszak, 2018). One of the most

critical factors of their development is the creation of knowledge and new technological and organisational solutions for industry. Therefore, universities are required leaders of cluster initiatives bringing together knowledge of different disciplines with the practice (Claver-Cortés et al., 2020; Kolomytseva and Pavlovska, 2020; Reichert, 2019; Wyrzykowska, 2015). For these reasons, the development of clusters depends on collaboration with universities and other research institutions, which become initiators of joint research (Reichert, 2019). According to M.E. Porter (1998), clusters are the prevalent future of the globalised economy, because they create regional competitive advantage by enhancing productivity, innovation, and new business formation. Therefore, the concept of university-cluster collaboration (UCC) is economically and socially vital. This paper aims to investigate collaborative relationships that arise between agri-food clusters and universities. The article analyses an example of the Southern Wielkopolska Food Cluster (pl. Klaster Spożywczy Południowej Wielkopolski), which mainly develops modern distribution channels of food products produced by its participants (www.klaster.kalisz.pl).

MATERIALS AND METHODS

This research is a case study of a qualitative approach and descriptive. It develops and explores an analytical concept of university-cluster collaboration (UCC). The case investigated is a cluster cooperating with universities located in the region. The data come from a review of the literature, including theoretical and empirical studies, documentary and textual analysis of publications, reports and documents of the studied cluster, and semi-structured interview with the President and university representative in person as well as direct observation.

RESULTS AND DISCUSSION

The analytical concept of University-Cluster Collaborations (UCC)

Universities create values and impact society in several ways. Traditionally they carry out scientific research and education (Dobrowolski, 2016). Nowadays, in knowledge-driven economies, the third mission of universities is connected with the practice of innovation and entrepreneurship. Both of them are more dependent on interdisciplinary networks, clusters and ecosystems spanning across many organisational, institutional and cultural boundaries, and facilitate by geographical and social proximity. The practical involvement of universities includes research partnerships, collaborations as well as services for industry partners located in the vicinity of industrial areas (Claver-Cortés et al, 2020; Kaloudis et al., 2019; Ankrah, and AL-Tabbaa, 2015). Commonly found tensions between universities and industry come mainly from diverse organisational perspectives, interests and objectives (Kaloudis et al., 2019; Ankrah, AL-Tabbaa, 2015). They may especially cause difficulties in triple helix clustering.

Table 4 Essential tensions between university and business and expected outcomes of UCC

Area	Tensions		Outcomes
	University	Business	
Knowledge	Creation, education, theorisation, cognition	Innovation, implementation, commercialisation	Sharing and co-creation of knowledge
Method	Systemic, interdisciplinary	Technological specialisation	Addressing social and ecological challenges
Financing	Public or private funding	Self-financing	Fundraising, profiting
Time horizon	Long-term, solutions to scientific problems	Short-term, solutions to current, operational problems	Contract research and consulting for specific solutions
Tangible Resources	Research infrastructure	Technical facilities and equipment	Access to research and technological facilities
Intangible Resources	Reputation, prestige, legitimacy	Private and undisclosed modes of operation	Spin-offs, complementary expertise
Management	Bureaucratisation, formalisation	Flexible, unformal, project-and profit-oriented	Managerial and networking skills
Research	Basic, public dissemination of research outcomes, citations	Applied, professional and technological confidentiality, patents	Collaborative or sponsored research, research partnerships and publications

Source: own elaboration based on: Jami, Gökdeniz 2020; Alrajhi and Aydin 2019; Kaloudis et al., 2019, Signorini, 2019; Rybnicek and Königsgruber, 2018; Zhou, 2017; Ankrah and AL-Tabbaa, 2015.

However, there are also drivers of social capital resources, such as commitment, trust and ongoing long-term relations between partners, especially for reducing commonly found tensions (Kaloudis et al., 2019). The successful academic leadership focuses on long-term strategic partnerships with a shared vision and strategy to achieve goals. The key individuals with an understanding of both academic and business worlds are the driving force behind successful partnerships (Awasthy et al., 2020; Kaloudis et al., 2019). When mutual understanding and ability to overcome the barriers are more potent than cultural and organisational differences, tensions, and conflicts, then expected outcomes are possible including mainly obtaining necessary resources and generating synergies of UCC (Table 1).
The importance of the UCC differs across scientific fields and industry sectors. Some studies indicate that specific industry sectors and scientific fields have significant potential for cooperation (Kotiranta et al., 2020; Kaloudis et al., 2019; Bekkers and Freitas, 2008). Science-intensive sectors such as biotechnology,

pharmaceuticals and chemicals have strong complementarities with basic academic research and tend to rely on research partnerships and to some degree on research services (Kaloudis et al., 2019). Also, agricultural and economic sciences show significantly higher propensities to interact with industry and have higher intensities of interaction. Increased powers of exchange are in more resource-oriented sectors like agriculture. In particular, in agri-food industries, cross-science and cross-sectoral knowledge sharing are essential for sustainable development (González-Morenoa et al. 2019; McKelvey, Ljungberg 2017). Knowledge interactions of agri-food sectors are on a few fields of science, like agricultural engineering, biology, chemistry or economics (Schartinger et al., 2002). Such sectors as food production rely more heavily on university research than others.

State of agri-food clusters in Poland

Poland's agri-food sector produces a variety of agricultural, horticultural and animal origin products. It is one of the most important and influential areas of the Polish economy (Kiełbasa, 2015). However, over the last 30 years, the Polish economy has experienced many changes and transformations, and the Polish agri-food sector has undergone a significant shift. It evolved from a relatively backward sector, using outdated technologies and production methods, has grown into a modern and dynamic business (Igras, 2014; Kiełbasa, 2015; Szczepaniak and Wigier, 2020, Wigier, 2014, Figiel 2014). Agri-food sector is currently the fourth largest sector of the economy in Poland, and its contribution to the country's GDP is much higher than the EU average (Igras, 2014). In 2019, the agri-food sector accounted for 2.5% of the total value-added, and it employed nearly 9.0% of the economically active population (EC, 2020). In the last 30 years, the competitiveness of the Polish agri-food sector has significantly increased in the European and global markets (Kowalski and Wigier, 2014).

Investigation of clusters in the agri-food sector began in the first decade of the 20th century (Stryjakiewicz and Dyba, 2014). In Poland, the early research on clusters dates back to 1989. In 2002, an analysis showed 18 sets located in 8 voivodeships (Szultka and Brodzicki, 2004). At the end of 2007, there were 33 clusters in Poland, including only one agri-food cluster, namely Ecological Food Valley Cluster of University of Entrepreneurship and Administration in Lublin (PARP, 2012; Kacprzak, 2014; Słoniec et al., 2016). Until 2012, there was a total of 212 cluster initiatives, including 20 in the agri-food sector (PARP, 2012). In 2015 cluster map included 134 clustering groups operating in Poland, including 5 clusters in the food industry (Buczyńska et al., 2016).

Although there are about 20 initiatives in the food industry clusters, they are significantly fragmented. There are three initiatives in each Lublin, Łódź, Podlaskie and Warmińsko-Mazurskie voivodship, and the other cluster initiatives scatter across the other twelve voivodships. Clusters in Poland are both strictly sectoral and regional (Wierzejski and Nasalski, 2014). Several Polish regions distinguish for clustering (www.clusterobservatory.edu/data). The potential of

these regions is very favourable in the context of the possibility of creating new cluster structures (Wierzejski and Nasalski, 2014).

The activity of the Southern Wielkopolska Food Cluster

The Southern Wielkopolska Food Cluster (pl. Klaster Spożywczy Południowej Wielkopolski) was established in the form of an association on the initiative of three regional chambers on the 16th of September in 2009 (Spychalski, 2014). It currently has 37 regular members, including numerous R&D institutions. The mission of the Association is to create in the southern Wielkopolska a stable and robust organisation able to meet the continually changing needs of the agri-food sector (Spychalski, 2014).

Various factors determine the cluster's efficient operation. The internal one comes from clustering companies and in particular from the relations between them. Other factors are external related to the area, mezzo and macro environment. The critical success factors of cluster organisations are: advantageous location to sources of supply and proximity to partners (Hinzmann et al., 2019), production and service traditions and work culture and level of knowledge in the field (Isaksen, 2016), experience in developing new technologies (Ibragimova and Golovkin, 2019), experience and skills of management staff (Kamath et al., 2012), the ability to monitor the environment, forecast changes and plan strategically (Klofsten et al., 2015), a high level of automation in production processes (Götz, Jankowska, 2017) and mutual trust in relations between cluster participants (Mueller and Jungwirth, 2016). These factors are discussed below in the context of the South Wielkopolska Food Cluster.

The critical condition for the excellent functioning of the industrial cluster is its convenient location to crucial resources. The studied cluster has located in the area of intensive cultivation of vegetables and fruits since the inter-war period thanks to the agricultural and food processing plants created in this region in Pudliszki and then in Kotlin. Large processing factories caused agricultural and fruit production to flourish in this region. Along with agri-food processing, machine manufacturers for the agri-food industry develops. In this way, it creates a group of companies living in symbiosis. The industrialisation of the local agri-food sector allowed to increase the productivity of production factors and, consequently, created a regional competitive advantage. The long-term specialisation of companies has allowed to gather knowledge and create a unique working culture supported by the experience of employees.

Geographical proximity, although it significantly facilitates companies to establish useful contacts and a better understanding of the needs of business partners is not always a guarantee of mutual trust among cluster participants. In turn, mutual trust is necessary to take advantage of the specialisation and to take joint but usually burdened with risk and uncertainty, initiatives often with effects visible in the distant future. Therefore, the priority objective in the initial stage of cluster development is to get to know each other's members and build mutual trust against grounded competitive behaviour. It is worth noting that the companies participating in the cluster mostly belong to small and medium-sized enterprises, and

fragmentation (and low economic power) is one of the essential prerequisites for cooperation to achieve common goals such as assortment promotion or the search for business partners and also joint research and development projects. Showing the benefits of collaboration for companies operating on similar markets and in the same areas of production or services is the primary task of the cluster authorities. Often the role of an impartial but also objective entity bringing together competitors is taken over by independent organisations such as scientific institutions or local authorities. In the case of the studied cluster, this role is played by the local government, whose representative coordinates the work of the cluster.

Engaging in joint activities aimed at increasing the competitiveness of the group and the region requires a full understanding of the top management in individual companies. Therefore one of the objectives of the cluster should be to invest in the development of knowledge and management skills of the associated companies. That is why the steering committee of the group informs its members about the possibilities of training. It also organises and finances workshops and networking events. The members also participate in knowledge transfer by organising internships and classes for students of profiled schools, thus influencing the quality of available human and social capital.

One of the most valuable competencies of each cluster and at the same time strongly linked to other key performance factors is the creation of new technologies that have the potential to improve the competitive position of individual companies significantly and ultimately the whole cluster. This area requires close cooperation of different types of entities - manufacturing or service companies, scientific institutions, often also financial entities. Due to the involvement of significant resources and stretching over time of research, the R&D projects require coordination. They usually burden with high risk, so it is crucial to initially support joint initiatives by local authorities as well as by low-interest or non-refundable external funding reducing the perceived costs of cooperation and risk in development projects. Several times the cluster has obtained non-refundable grants from the EU and national and local sources, for investments. In particular, the cluster was the beneficiary of a large EU grant, which financed the modern ICT equipment. It launches its server, Internet portal and Virtual Commodity Exchange connected to the IT systems of clustering companies (Spychalski, 2014).

The cluster's activity in recent years has decreased, which can be associated with a lack of continuity of financial support. Undoubtedly, cluster initiatives in many cases require a long incubation period and the coexistence of many success factors to maintain their sustainability after the end of external financial support.

In the studied cluster, two barriers of collaboration are key ones - lack of well-educated and trained staff in companies and lack of funds, and on the second stage difficulties in communication and lack of information about the activities of the other party. And last but not least the cluster can boast of many initiatives that rely on the scientific and research training of its particular members; however, cases of spontaneous cooperation of cluster members in research and development projects are rare.

The collaboration of Southern Wielkopolska Food Cluster with universities

The studied cluster collaborates with four research institutions and three universities located in the region. The location of cooperating universities and research centres is in the vicinity of the cluster industrial area of activity. The cluster seems as being facilitated by geographical, cognitive, and social proximity to the universities mostly located in Poznan city - the capital of the region. Clusters often collaborate with several universities to meet their objectives. In this context, the concept of collaborative advantage is gaining momentum within academia, where universities and research institutions operating in different spheres had begun to collaborate to provide support for a particular industry (Alrajhi, Aydin 2019, p 171-172). This momentum could be possible within the setup of the strategic university-cluster research centre.

The President of the cluster represents the university. He was the initiator of the entry of his alma mater into the group. He is currently the cluster academic representative and a signatory of the letter of intent between the cluster and the faculty dean. The university participation does not connect with the need to pay any financial contributions, but it also does not involve any costs on the part of the cluster. The President indicated that the cluster development depends primarily on the EU funds and projects.

The President of the cluster seems to be the key individual in the industry-university collaboration process. He claims the desire to combine the worlds of business and science, as well as an attempt to commercialise scientific ideas by the company and vice versa. This example confirms the results of other studies which indicate, that the variety and frequency of interactions with cluster, is not explained by the rankings of the university departments, but rather by the researchers' characteristics and motivations (Kaloudis et al., 2019, p.49-51). On the one hand, the President of the cluster has a high degree of cognitive proximity and mutual understanding regarding university and cluster interaction, within both academic and agri-food sectors.

The collaboration of the studied cluster with universities consists mainly of taking the initiatives toward research services targeted for problem-solving activities, in which they obtain assistance from university researchers. Universities, on the other hand, are slow to take the initiative of a university-cluster research centre. The President of the cluster claims that '*the role of the university is rather the role of individual colleagues from universities, who represent universities in the cluster. Without my initiative, the university does not show such activity'*. So far, the most active in cooperation with the cluster has been the department represented by the cluster president. He underlines, that the most benefits from collaboration result from the commercialisation of research, exchange or transfer of knowledge, and research contracted by companies and to a lesser extent from training. It confirms the results of research carried out in other countries indicating that industry mainly initiates universities initiate research services and research partnerships. Business

generally desires more applied research, while universities generally strive for basic research (Kaloudis et al., 2019, p.46-47).

The cluster has positive experiences from projects in collaboration with universities. Its partners claim that lack of broader interest in cooperation, extensive formalisation and bureaucratisation of universities hinders collaboration. Likewise, the literature, indicates that slow academic bureaucracies may stifle technology commercialisation, depress the firm's performance and delay the fulfilment of the firm's objectives (Ankrah, AL-Tabbaa 2015, p.399). In the studied cluster President opinion, quite often initiatives are taken to invite researchers to present the university offer to business. Business is quite sceptical about such actions, due to the lack of a specialised intermediary unit and initiative on the part of the university. Individual members of the cluster also cooperate independently with colleagues, in no small extent, it bases on good mutual relations and exchange of experience and knowledge. The example confirms research carried out in other countries, which shows that intermediary collaboration centres set up at universities significantly increase the level and effectiveness of university-business cooperation. The role of university research centres is essential, as it is mandatory that in the management of it universities participate in all critical decision-making processes (Kolomytseva, Pavlovska, 2020, p.55-56; Kaloudis et al., 2019, p.45; Awasthy et al. 2020, p.51-53; Ankrah, AL-Tabbaa 2015, p.396). On the other hand, it requires skills and activities performed by business/cluster representatives to manage the knowledge stemming from universities successfully.

The President declared that the relationships with local and regional governments are excellent and they significantly influence the cluster activity, despite the lack of funding from the authorities. '*In my opinion, the cluster very often participates in many regional initiatives and more. We are active based on even international and national initiatives. We often prepare reports, recommendations etc. Local government units notice us*'. The universities are seen by business and local authorities as a link to the dots of local networks. For compelling connect the dots, the university has to be highly responsive, adaptable, strategically directed, autonomously governed, and densely interlinked with its regional partners as well as an international network (Reichert 2019, p.7). These new roles of orchestrating multi-actor knowledge creation require profound, systematic institutional transformations of universities and financial participation of all actors, in particular local and regional governments.

CONCLUSIONS

The UCC should be incorporated into agri-food policies and regulations to stimulate green innovations and new instruments for food quality and safety. The governments should intensify the adoption of measures to encourage and improve collaboration between agricultural universities and the agri-food industry. It tailors policies and responsive to the specific needs of industry and university actors.

Universities need to redefine their mission, and collaboration with industry clusters needs to be in include as an essential part of the role of research universities.

Universities must involve people with networking and managerial skills to attract industry partners. At the same time, academics with industry background are an added value as they are expanding more willing to cross boundaries and network with people beyond their area of expertise. Intermediary organisations in the form of research centres, in particular, cluster initiative centres, may play a crucial role in a vital economy and society. The main objective would be to promote and establish personal contacts between scientists and entrepreneurs. They should be set up at universities, including life sciences and management, to facilitate interdisciplinary and inter-sectoral collaboration in the agri-food industry.

ACKNOWLEDGEMENT

This research is carried out in the frames of the Project "Enhancing capacity of universities to initiate and to participate in clusters development on innovation and sustainability principles" (UniClaD) KA2 no 609944-EPP-1-2019-1-LT-EPPKA2-CBHE-JP, co-funded by the Erasmus+Programme of the European Union.

REFERENCES

Alrajhi A.N., Aydin N. (2019). Determinants of effective university-business collaboration. Empirical study of Saudi universities, Journal of Industry-University Collaboration, Vol 1(3), 169-180.

Ankrah S., AL-Tabbaa O. (2015). Universities—industry collaboration: A systematic review, Scandinavian Journal of Management 31, 387-408.

Awasthy R., Flint S., Sankarnarayana R., Jones R.L. (2020). A framework to improve university-industry collaboration, Journal of Industry-University Collaboration, Vol.2 (1), 49-62.

Bekkers R., I.M.B. Freitas (2008). Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter? Research Policy, 37, 1837-1853.

Buczyńska G., Frączek D., Kryjom P. (2016). Raport z inwentaryzacji klastrów w Polsce 2015. Polska Agencja Rozwoju Przedsiębiorczości (Polish Agency for Enterprise Development), Warsaw. Retrieved from: https://www.parp.gov.pl/storage/publications/pdf/20160314_152947%20raport_inwentaryzacja_klastrow_w_polsce_2015_v_2_0.pdf, accessed: 20.08.2020.

Claver-Cortés E., Marco-Lajara B., Seva-Larrosa P., Ruiz-Fernández L. and Sánchez-García E. (2020) Explanatory Factors of Entrepreneurship in Food and Beverage Clusters in Spain, Sustainability, 12(14), 5625, 1-22.

Dobrowolski Z. (2016). The role of universities in XXI century, [In:] Sułkowski Ł., Noworól A., Mazurek-Kucharska B. (Eds.), Humanistyczne aspekty zarządzania wiedzą i kompetencjami, Zarządzanie i Przedsiębiorczość, XVII Tom, 7 Zeszyt, I część, Wydawnictwo Społecznej Akademii Nauk, Lodz-Warsaw, Poland, 31-42.

European Cluster Observatory (2015). Cluster Mapping 2015. Retrieved from: http://www.clusterobservatory.eu/data, accessed: 27.08.2020.

European Commission (2020). Statistical Factsheet. Poland. June 2020. Retrieved from: https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/farming/documents/agri-statistical-factsheet-pl_en.pdf, accessed: 24.08.2020.

Figiel Sz. (2014). Development of exporting clusters in the context of international competitiveness of the Polish agri-food sector, [In:] Kowalski A., Wigier M. (Eds.), competitiveness of the Polish food economy in the condition of globalisation and European integration. Multi-Annual Programme 2011-2014. Competitiveness of the Polish food economy under the conditions of the globalisation and European integration. Institute of Agricultural and Food Economics National Research Institute, Warsaw, 137-150.

González-Morenoa Á., Triguerob Á., Sáez-Martínezа F. J. (2019). Many or trusted partners for eco-innovation? The influence of breadth and depth of firms' knowledge network in the food sector, Technological Forecasting & Social Change 147, 51-62.

Götz M., Jankowska B. (2017). Clusters and Industry 4.0 – do they fit together? European Planning Studies, 25(9), 1633–1653. https://doi.org/10.1080/09654313.2017.1327037

Hinzmann S., Cantner U., Graf H. (2019). The role of geographical proximity for project performance: Evidence from the German Leading-Edge Cluster Competition. The Journal of Technology Transfer, 44(6), 1744. https://doi.org/10.1007/s10961-017-9600-1

Ibragimova R., Golovkin D. (2019). Key factors of the development of the conditions for innovation industrial cluster development. Вестник Пермского Университета: Серия Экономика, 14(1), 177–192. https://doi.org/10.17072/1994-9960-2019-1-177-192

Igras J. ed. (2014). 25 years of Polish Agriculture. Food Security in Europe. Puławy Competence Center, Retrieved from: http://www.ckpulawy.com/files/The%20Report_25%20years%20of%20Polish%20agriculture.pdf, accessed: 20.08.2020.

Isaksen A. (2016). Cluster emergence: Combining pre-existing conditions and triggering factors. Entrepreneurship & Regional Development, 28(9/10), 704 - 723. https://doi.org/10.1080/08985626.2016.1239762

Jami M.Y., Gökdeniz I. (2020). The Role of Universities in the Development of Entrepreneurship, Przedsiębiorczość-Edukacja [Entrepreneurship-Education], 16(1), 85-94.

Kacprzak E. (2014). Funkcjonowanie klastrów rolno-żywnościowych na ekologicznym rynku rolnym w Polsce. Rozwój Regionalny i Polityka Regionalna 26/2014, 119-134. Uniwersytet im. Adama Mickiewicza w Poznaniu, Poznań. Retrieved from: https://pressto.amu.edu.pl/index.php/rrpr/article/view/5665, accessed: 25.08.2020.

Kaloudis A., Aspelund A., Koch P.M., Lauvås T.A., Mathisen M.T., Strand Ø., Sørheim R., Aadland T. (2019). How Universities Contribute to Innovation: A Literature Review-based Analysis, Report 2019, NTNU, Trondheim, Norway.

Kamath S., Agrawal J., Chase K. (2012). Explaining Geographic Cluster Success-The GEMS Model. American Journal of Economics & Sociology, 71(1), 184–214. https://doi.org/10.1111/j.1536-7150.2011.00819.

Kiełbasa M. (2015). Przyszłość sektora rolno-spożywczego w Polsce w odniesieniu do stanu obecnego. Progress in Eonomic Sciences, 2, 227-238.

Klofsten M., Bienkowska D., Laur I., Sölvell I. (2015). Success Factors in Cluster Initiative Management: Mapping Out the 'Big Five'. Industry and Higher Education, 29(1), 65–77. https://doi.org/10.5367/ihe.2015.0237.

Kolomytseva O., Pavlovska A. (2020). The role of universities in the national innovation system, Baltic Journal of Economic Studies, 6(1), 51-58.

Kotiranta A., Tahvanainen A., Kovalainen A., Poutanen S. (2020). Forms and varieties of research and industry collaboration across disciplines, Heliyon 6, 1-18.

Kowalski A., Wigier M. (Eds.) (2014). Competitiveness of the Polish food economy in the condition of globalisation and European integration. Multi-Annual Programme 2011-2014. Competitiveness of the Polish food economy under the conditions of the globalisation and European integration. Institute of Agricultural and Food Economics National Research Institute, Warsaw.

McKelvey M., Ljungberg D. (2017). How public policy can stimulate the capabilities of firms to innovate in a traditional industry through academic engagement: the case of the Swedish food industry, R&D Management 47(4), 534-544.

Mueller E. F., Jungwirth C. (2016). What drives the effectiveness of industrial clusters? Exploring the impact of contextual, structural and functioning determinants. Entrepreneurship & Regional Development, 28(5/6), 424–447. https://doi.org/10.1080/08985626.2016.1186748.

PARP - Polska Agencja Rozwoju Przedsiębiorczości (2012). Klastry w Polsce. Katalog. Warszawa.

Porter M. E. (1998). Clusters and the new economics of competition, Harvard Business Review 76(6), 77-90.

Reichert S. (2019). The Role of Universities in Regional Innovation Ecosystems, EUA Studies, European University Association, Brussels, Belgium.

Rybnicek R., Königsgruber R. (2018). What makes industry–university collaboration succeed? A systematic review of the literature, Journal of Business Economics 89, 221–250.

Schartinger D., Rammer Ch., Fischer M.M., Fröhlich J. (2002). Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants, Research Policy 31, 303-328.

Signorini G.F. (2019). Open Source and Sustainability: The Role of University, [In:] Leal F. W., Bardi U. (Eds.) Sustainability on University Campuses: Learning, Skills Building and Best Practices. World Sustainability Series. Springer, Cham.

Słoniec J., Zaragoza Sáez P.C., Marco-Lajara B. (2016). Clusters into Poland and Spain: comparative case study of two clusters from the agricultural industry.

Odessa National Polytechnic University. Economics: time realities. 2016, 2(24): 6-14.

Southern Wielkopolska Food Cluster (pl. Klaster Spożywczy Południowej Wielkopolski, www.klaster.kalisz.pl, accessed: 20.08.2020.

Spychalski A. (2014). Warunki, obszar i założenia do działania Sieci Współpracy Aglomeracji Kalisko-Ostrowskiej. Raport końcowy Zespołu Projektowego opracowany w ramach projektu: POKL „Sieć Współpracy Aglomeracji Kalisko-Ostrowskiej" współfinansowanego ze środków Europejskiego Funduszu Społecznego. http://www.rigkalisz.pl/opracowania.html, accessed: 20.08.2020.

Stryjakiewicz T., Dyba W. (2014). Organizacja przestrzenna i funkcjonowanie klastrów w województwie wielkopolskim. Wielkopolskie Regionalne Obserwatorium Terytorialne. Poznań.

Szczepaniak I., Wigier M. (2020). Polski biznes rolno-spożywczy wczoraj i dzisiaj – czynniki sukcesu. [In:] R. Przygodzka, E. Gruszewska (Eds.) Instytucjonalne i strukturalne aspekty rozwoju rolnictwa i obszarów wiejskich. Księga poświęcona pamięci dr hab. Adama Sadowskiego Profesora Uniwersytetu w Białymstoku, Białystok, p. 233-256.

Szultka S., Brodzicki T. (Eds.) (2004). Klastry - innowacyjne wyzwanie dla Polski. Instytut Badań nad Gospodarką Rynkową. Gdańsk.

Wierzejski T., Nasalski Z. (2014). Rola klastrów w procesie internacjonalizacji polskiego sektora rolno-spożywczego. Problemy Rolnictwa Światowego No 14(29)/2, 238-246. Retrieved from: http://cejsh.icm.edu.pl/cejsh/element/bwmeta1.element.cejsh-from-agro-e82834df-d279-4b45-b614-7d9114ea6d7b?q=bwmeta1.element.cejsh-from-agro-7f527d9c-e349-4e55-af9b-d1c76a2e386c;13&qt=CHILDREN-STATELESS, accessed: 20.08.2020.

Wigier M. (Ed.) (2014). Food economy and rural areas in Poland – structural changes and effectiveness of public policy. Multi-Annual Programme 2011-2014. Competitiveness of the Polish food economy under the conditions of globalisation and European integration. Institute of Agricultural and Food Economics National Research Institute. Warsaw.

Wiśniewska-Paluszak (2018). Sieci agrobiznesu w świetle teorii ekonomii, Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu, Poznań.

Wyrzykowska B. (2015). Współpraca nauki i przemysłu rolno-spożywczego na przykładzie Klastra Innowacji w Agrobiznesie, Problemy Zarządzania 13(1), 166-181.

Zhou D. (2017). The Research on the Functions of Universities in an Innovation Cluster and the Realisation Mechanisms, Open Journal of Business and Management 5, 63-72.

Original Scientific paper
10.7251/AGRENG2002144B
UDC 638.132(65)

STUDY OF MELLIFEROUS PLANTS VISITED BY THE WORKER HONEYBEE, *APIS MELLIFERA* INTERMISSA IN BOUMERDES, ALGERIA

Messaouda BELAID[1]*, Arezki MOHAMMEDI[1], Nora CHAHBAR[1], Fatma ACHEUK[1], Malika ABBAD-BENNOUR[3], Amel IGHIL AMEUR[2]

[1]Laboratory of Valorisation and Conservation of Biological Resources (VALCOR). Faculty of Sciences. M'Hamed Bougara Boumerdes University, Algeria
[2]Department of Biology. Faculty of Sciences. M'Hamed Bougara Boumerdes University, Algeria
[3]Faculty of Biological Sciences and Agronomic Sciences, Mouloud Mammeri University, Tizi-Ouzou
*Corresponding author: belaidfo@yahoo.fr; m.belaid@univ-boumerdes.dz

ABSTRACT

This work allows to establish a list of melliferous plants visited by the worker bee, *Apis mellifera intermissa* in Boumerdes through melissopalynological analysis. Eight samples of honey were collected in summer from different regions of Boumerdes province in Algeria: Mizrana (H1), Tizéruine (H2), Tagdempt (H3), Sherraba (H4), Baghlia (H5), Boudouaou (H6), Sidi Daoud (H7) and Si Mustapha (H8). For the analysis, we adopted the classical method of Louveaux *et al*., (1970). The results obtained showed that the melissopalynological analysis indicated the pollen grains of *Eucalyptus* were numerous as more than 45% of the pollen in six (6) of the eight samples of Boumerdes (H1, H2, H3, H4, H7 and H8). The pollen of *Hedysarum coronarium* was dominant in the sample H5 (67.60%). In seven samples honey recognized multifloral by beekeepers, *Eucalyptus* and *Citrus* taxa were respectively super represented and underrepresented in the honey H7 (87.46%) and H6 (19.80%). Thus, the number of taxa listed in the honeys studied varies from 14 to 19. The total number of pollen grains counted for the 8 samples varied from 646 to 3580.

Keywords: *Honey, melliferous plants, melissopalynology, Boumerdes province.*

INTRODUCTION

Honey contains pollens grains provided from foraging activity of honeybees that reflet the environmental location of beehives (Von Der Ohe *et al.*, 2004). The pollen is a natural source of protein for bees and it is necessary for the honeybee's development (Radev *et al*., 2018). The composition of pollen harvested by honeybees can vary greatly on the time of year, the botanical origin and the geographic region from which the pollen is obtained (Von Der Ohe *et al.*, 2004). The only surefire way to issue the "identity card" of a honey is to do its pollen

analysis, because honey contains countless grains of pollen (several million in a single kilogram of honey) and honeydew elements. Each honey carries within it the mark of its origin defined by the pollen of the flowers pollinated by the bees which harvested the nectar (Louveaux, 1985). Pollen analysis of honey or melissopalynology is a valuable diagnostic tool for the possibility to determine the botanical and geographical origin of honey (Von Der Ohe *et al*., 2004).

The importance of identified taxa in honeys provides an image of the plant environment in the bees' forage area (Louveaux, 1985). In the world, several studies are devoted to the study of botanical ressources through palynological analysis (Feller, 1979; Valencia-Barrera *et al*., 1994, Kaya *et al*. 2005; Sajwani *et al*., 2007; Ayansola & Davies 2012; Dukku, 2013; Iritie *et al*., 2014). In Algeria, this field is far from being explorable (Ouchemoukh *et al*., 2007; Chefrour *et al*., 2009; Benaziza-Bouchema & Schweitzer, 2010; Makhloufi *et al*., 2010).

The purpose of this work is to establish a list of melliferous plants visited by the worker bee, *Apis mellifera intermissa* in Boumerdes through melissopalynological analysis.

MATERIAL AND METHODS

Samples collection

Honeys samples from *Apis mellifera intermissa* are collected in summer from different regions of Boumerdes province (Algeria): Mizrana (H1), Tizéruine (H2), Tagdempt (H3), Sherraba (H4), Baghlia (H5), Isser (H 6), Sidi Daoud (H7) and Si Mustapha (H8). They were obtained by centrifugation and stored at 10 ° C until analysis.

Palynological analysis

For the palynological analysis of honey, we adopted the classical method described by the International Commission for Bee Botany ICBB (Louveaux *et al*., 1970). This method consists in dissolving 10 g of each honey sample in 100 ml of warm distilled water at 40 ° C. After centrifugation at 3000 rpm for 5 to 10 minutes and after decantation, the pellet is put on a slide covered with coverslip and analysed by using light microscope at the magnification 400 to 1000x .

Pollen determination level

According to Louveaux *et al.*, (1970), when detailed knowledge is lacking or when, for reasons of time, a finer determination has to be abandoned, the pollen can be attached to a larger group (form or type). These two terms are used to indicate all genera or species represented by the same morphological type.

Expression of results

According to Gadbin (1980), the counts were carried out until the percentages and the number of taxa stabilized. Identified taxa being grouped into "Pollen dominant" (more than 45% of the total pollen grains counted), "secondary pollen« (16-45%), «important minor pollen" (from 3 to 15%), "rare pollen» (less than 3%). The

identification of different pollen taxa is based on pollen reference collections and publications (Louveaux, 1977; Gadbin, 1980; Sawyer, 2010).

A honey is classified as unifloral (monofloral) if it contains pollen in quantities exceeding 45% on the remaining pollen identified. Honey containing a variety of pollen types, none of which reaches 45%, are classified as multifloral (Darrigol 1979; Sawyer, 2010). According to Sawyer (2010) and Corvucci *et al.*, (2015), these are general some exceptions depending on the type of pollen. Many pollen types are underrepresented (*Citrus* spp, *Tilia* spp, *Helianthus*, *Rosmarinus…*) or overrrepresented (*Casanea sativa*, *Eucalyptus* spp…). For instance, to characterize acacia honey as unifloral, *R.pseudoacacia* pollen must be over 15%, *Citrus* must have at least 10% of *Citrus* spp, 20 to 30% for *Tilia.* Von Der Ohe *et al*., (2004) recommended content over 83% for *Eucalyptus* spot be unifloral honey. Several pollen types that could not be identified were designed as unknowns.

RESULTS AND DISCUSSION

The pollen analysis improves our knowledge on the honey flora of the different sites studied and on the food resources available to bee *Apis mellifera intermissa* under the conditions of our country. The results obtained are shown in Table 1.

Table 1. Different types of pollen from Boumerdes honey samples (in percent)

Familly	Species	H1	H2	H3	H4	H5	H6	H7	H8
Apiaceae[1]	*Daucus carotta*	0.93	0.68	0.33	1.46	1.87	13.15	0.86	0.22
Asteraceae	*Chrysanthemum myconis*	1.4	-	-	0.69	2.06	-	-	-
	Taraxacum officinais	-	11.17	-	-	1.20	-	-	-
	Galactites tomentosa	3.75	7.86	0.13	0.12	1.68	02.32	0.36	0.02
	Helianthus annus	4.96	-	-	-	1.93	-	-	-
	Inula viscosa	0.6	-	0.08	0.54	0.46	-	0.5	0.05
Borraginaceae	*Borrago officinalis*	3.69	0.05	-	-	-	02.63	0.21	-
	Echium plantagineum	2.48	2.27	6.59	16.94	3.34	4.02	1.8	5.81
Caryophyllaceae	*Lycnis sp*	-	-	-	-	0.06	-	-	-
Convolvulaceae	*Convolvulus arvensis*	-	1	0.08	-	-	-	-	0.3
Cruciferae[2]	*Raphanus raphanistrum*	-	2.22	-	0.3	-	-	-	0.08
	Brassica napus	1.34	2.22	0.39	0.82		-	1.73	0.96
	Sinapis arvensis	1.54	1.16	0.08	-	-	-	-	-
Ericaceae	*Erica arborea*	0.2	-	0.02	0.69	-	2.32	-	-
Lamiaceae[3]	*Lavandula stoechas*	0.13	-	039	0.30	1.60	2.78	0.5	0.08
	Rosmarinus officinalis	0.2	0.2	-	0.17	-	-		-

Myrtaceae	*Eucalyptus sp*	49.36	58.04	73.07	64.21	11.69	04.02	87.46	81.81
Oxalidaceae	*Oxalis prescaprae*	3.02	0.47	0.61	0.56	-	1.85	0.57	0.2
Papillionaceae [4]	*Trifolium sp*	2.95	0.21	0.33	0.77	4.94	-	0.36	0.85
	Hedysarum coronarium	10.33	3.28	3.49	6.45	67.60	29.55	2.31	4.61
	Robinia pseudoacacia	1.81	1.48	0.15	0.34	0.53	04.95	0.07	0.58
Rosaceae	*Pyrus- Prunus* type	7.57	7.93	4.83	4.45	0.40	3.71	1.8	2.57
	Rubus type	-	-	-	-	0.26	2.01	-	-
Rutaceae	*Citrus sp*	2.88	0.1	0.75	0.47	-	19.80	0.66	1.58
Tiliaceae	*Tilia sp*	-	-	-	-	-	4.64	-	-

- : absent, H: Honey, 1. Apiaceae or Umbelliferae, 2. Cruciferae or Brassicaceae, 3. Lamiaceae or Labiateae, 4. Papillionaceae or Fabaceae

The exploitation of Table 1 shows that Mizrana honey (H1) is characterized by the dominance of *Eucalyptus* sp pollen (49.36%). Compared to the other samples of honeys studied, this pollen taxon represents the lowest percentage. H1 is characterized by the abundance of *Hedysarum coronaruim* (Sulla) and *Pyrus-Prunus* type. The microscopic analysis of Tizeruine honey (H2) reveals the dominance of Eucalyptus sp (58.04%). This honey is very characteristic of the abundance of *Taraxacum officinalis*, *Galactites tomentosa*, and *Pyrus- Prunus* type. The Sherraba region (H4) is characterized by the dominance of *Eucalyptus* sp (64,21%). This pollen taxon is associated with *Hedysarum coronarium* and *Pyrus-Prunus* type which reaching the level of important isolated pollen. *Echuim plantagineum* reaches the level of the secondary pollen. In samples H7, H8 and H3, the predominance of *Eucalyptus* reflects the important harvest on this species, which reaches, as pollen analysis shows, the highest percentage respectively 87.46%, 81.81% and 73.07%. In Tagdemt region (H3), *Echuim plantagineum*, *Pyrus Prunus* type and *Hedysarum coronarium* respectively reached 6.59%; 4.83% and 3.49%. Comparatively to others honey, *Hedysarum coronarium* reached the lower percentage (2.31%) in the sample of Sidi Daoud (H7). In later region (H8), *Eucalyptus* pollen was accompanied respectively with *Echuim plantagineum*, *Hedysarum coronarium* and *Pyrus -Prunus* type.

Boumerdes regions were characterized by another's pollen types. *Hedysarum coronarium* pollen (67.60 %) and *Citrus* (19.80%) were dominant respectively in samples of Baghlia (H5) and Boudouaou (H6). *Eucalyptus* (11.69%), *Trifolium* sp (4.94%), *Echium plantagineum* (3.34%) and *Chrysanthemum myconis* pollen grains (2.06%) were concentrated in the first sample. The *Citrus* honey (H6) contained *Robinia pseudoacacia* (4.95%), Eucalyptus (4.02%), *Echium plantagineum* (4.02%), *Pyrus -Prunus* type (3.71%) and *Rubus* type 2.01%.

Microscopic analysis reveals that the honeys generally contain similar pollen, but in different combinations and percentages so the pollen spectrum shows some pollen characteristic and exclusive of a region. For example, pollen of *Helianthus*

annus is present only in honey H1 and H5. *Convolvulus arvensis* is only found in honeys H2, H3 and H8 (Table 2). The pollen grains of *Lycnis* and *Tilia* were present respectively only in samples H5 and H6. The pollens of *Daucus carotta, Galactites tomentosa, Echuim plantagineum, Hedysarum coronarium, Robinia pseudoacacia* are ubiquitous in all the samples studied.

In the family Asteraceae, we noted 5 types of pollen namely *Chrysanthemum myconis, Taraxacum officinalis, Galactites tomentosa, Helianthus annus* and *Inula viscosae.* In the Borraginaceae family, only 2 types are identified (*Borrago officinalis* and *Echium plantagineum*). The Cruciferae has 3 taxa *Raphanus raphanistrum, Brassica napus* and *Sinapis arvensis*. Lamiaceae contain 2 pollen species *Lavandula stoechas* and *Rosmarinus officinalis*. As for Papillionaceae, the *Trifolium* sp, *Hedysarum coronarium* and *Robinia pseudoacacia* are noted. For Rosacea, two taxa were identified (*Pyrus -Prunus* type and *Rubus* type).

Thus, the number of taxa listed in the honeys studied varies from 14 to 19 (Table 1 and Figure 1). This number is far from real, especially for samples H6, H5 and H2 (Figure 2). Note that the total number of pollen grains counted for the 8 samples from the different regions of Boumerdes varied from 646 to 3580 (Figure 3).

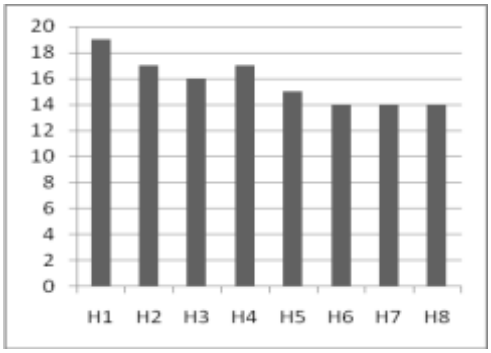

Figure 1 : Number of identified taxa pollen in the honey samples (H)

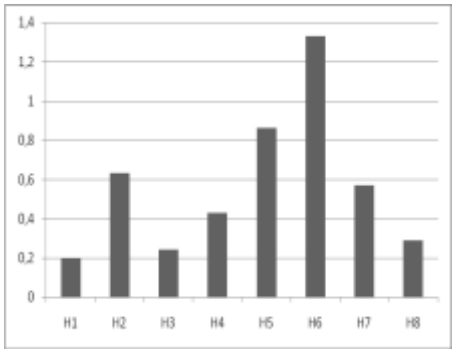

Figure 2 : Frequency of indeterminate honey samples(H)

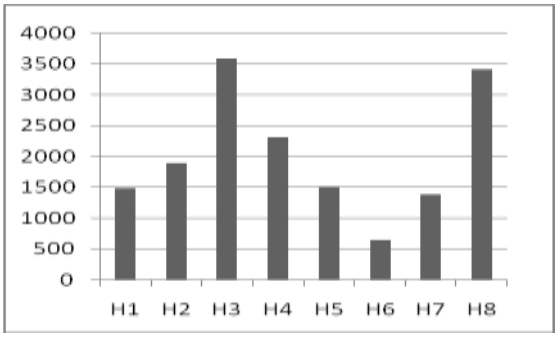

Figure 3: Total number of pollen grains counted in honey samples (H)

If we consider that families, Boumerdes regions are generally characterized by the richness of Myrtaceae, Papillionaceae, Borraginaceaes, Asteraceae and Rosaceae. Cruciferae, Rutaceas and Oxalidaceas are infrequent. The families of Apiaceae, Convulvulaceas, Ericaceaes and Lamiaceaes were found in trace amounts (Table 2 and Figure 4). There are 8 to 12 families in the different samples studied (Figure 5).

Table 2. Different Families of botanical resources visited by honeybees in Boumerdes honey samples (%)

Familly	H1	H2	H3	H4	H5	H6	H7	H8
Apiaceae	0.93	0.68	0.33	1.46	1.87	13.15	0.86	0.22
Asteraceae	10.46	19.03	0.11	1.35	7.33	2.32	0.86	0.07
Borraginaceae	6.17	2.32	6.59	16.94	3.34	6.65	2.01	3.81
Caryophyllaceae	-	-	-	-	0.06	-	-	-
Convolvulaceae	-	1	0,08	-	-	-	-	0.3
Cruciferae	2.88	5.60	0.47	112	-	-	1.73	1.04
Ericaceae	0.2	-	0.02	0.69	-	2.32	-	-
Lamiaceae	0.33	0.2	0.39	0.47	1.60	2.78	0.5	0.08
Myrtaceae	49.36	58.04	73.07	64.21	11.69	04.02	87.46	81.81
Oxalidaceae	3.02	0.47	0.61	0.56	-	1.85	0.57	0.2
Papillionaceae	9.11	5.44	4.58	8.12	73.07	36.35	3.31	6.34
Rosaceae	7.57	7.93	4.83	4.45	0.66	5.79	1.8	2.57
Rutaceae	2.88	0.1	0.75	0.47	-	19.80	0.66	1.58
Tiliaceae	-	-	-	-	-	4.64	-	-

- : absent

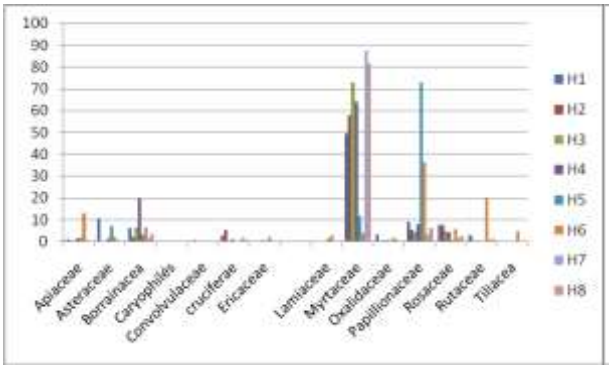

Figure 4: Occurrence of different families in Boumerdes honeys (H)

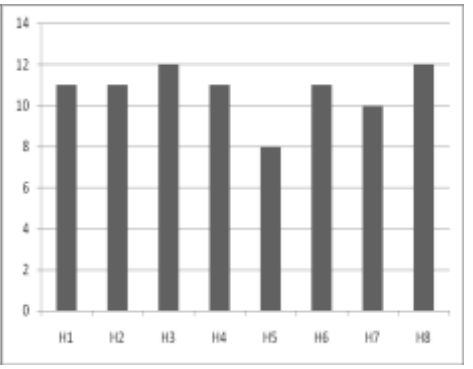

Figure 5: Number of families in each honey of Boumerdes

This work studies a number of plants that are sources of nectar and pollen for the honeybees (*Apis mellifera intermissa*) of Boumerdes regions. In seven samples honey recognized multifloral by beekeepers, Eucalyptus and *Citrus* taxa were respectively super represented and underrepresented in the honey H7 and H6. According to many researchers, the unifloral honey must contain a minimum of

45% of a single pollen type. Honey containing a variety of pollen types, none of which reaches 45%, are classified as multifloral (Darrigol 1979; Sawyer, 2010). According to Von Der Ohe *et al.,* (2004); Sawyer, (2010) and Corvucci *et al.*, (2015), these are general guidelines but many pollen types are underrepresented (*Citrus* sp) or overrrepresented (*Eucalyptus* spp). For instance, to characterize *Citrus* honey as unifloral, pollen must have at least 10% of *Citrus* sp, while for Eucalyptus honey, a content content over 83% is required to classify honey as unifloral. In the study, only the honey H7 and H6 respected this rule. Pollens taxa of *Eucalyptus* and *Citrus* reached respectively 87.46% and 19.80%. According to Sajwani *et al.,* (2007), *Eucalyptus* honey is a common type in Argentina and South Florida and California. Eucalyptus pollen is rare in honey of Oman. Louveaux and Abed (1984) have shown the importance of *Eucalyptus* in honey from the North Africa. This observation is confirmed by Ouchmoukh *et al.*, (2007); Chefrour *et al.* (2009); Benaziza-Bouchema and Schweitzer (2010) in Algerian honey. In a general way the secondary pollen present in these honeys is generally homogeneous. The pollens of *Citrus, Olea, Echium, Chamaerops*, Umbelliferae, are most often present in the Maghreb spectra. Botanical families such as Apiaceae and Ericaceae (Ouchemoukh *et al*., 2007), Papillionaceaes and Rosaceae (Chefrour *et a*l., 2009) are best represented respectively in honeys of northern and northeastern Algeria. According to Makhloufi *et al*., (2010), the accompanying pollen of *Eucalyptus* honey is *Echium plantagineum*, *Olea europaea*, *Trifolium* spp., *Papaver rhoeas*, *Centaurea* sp. and Apiaceae. Terrab *et al*., (2001), show that T*rifoluim*, *Citrus*, *Lythrum*, *Mentha* frequently appear in honeys from Northwest Morocco. Valencia-Barrera *et al*., (1994) noted in the province of Leon (Espagne), the most frequent families were Rosacea and Fabacea. Also, they reported in 27 honeys recognized multifloral honeys some pollen taxa were overrrepresented: *Lotus cornilatus, Trifoluim repens, Castanea sativa and Genista florida* type. Myrtaceae, Fabaceae, Asteracee, Proteaceae, Euphorbiacea, Fabaceae and Cistaceae were the best families represented respectively in Australian and Portuguese honey. Fabaceae, Asteraceae, Boraginacea, Cistacea and Scrophulriacea are the families with the highest quantity of pollen types in the samples from Spain (Seijo *et al*., 2003). The Asteracea, Fabaceae and Mimosacea are the most important families in Oman (Sajwani *et al*., 2007). In this work, *Eucalyptus* pollen is accompanied as previously mentioned by Papillionaceae, Myrtaceae and Rosaceaes. Valencia-Barrera *et al*., (1994) found in the province of Leon (Espagne), 22 types of pollen belonging to 5 families. A melissopalynological study of Turkys and Omani honeys, 122 pollen types representing 50 plants families and 86 taxa respectively were noted by Kaya *et al*., (2005) and by Sanjwni *et al*., (2007).

In our work, Boumerdes which characterises by the wide diversity of melliferous plants, these samples are also characterized by a low number of pollen types (14 to 19). Sajiwani *et al*., (2007) reported the low number of pollen types suggesting that the concentrated pollen of the dominant taxa provided enough nectar and pollen for honey production. Louveaux (1968) reports that various factors may be involved in determining the choice of forager. The plants that provide pollen and nectar at once

are preferred to others. Common plants existing in dense stands are also preferred. Localization and various ecological factors may also play an important role. This author also reports that the bee selected the rich pollens which bring him the maximum of the proteins. According to Rabiet (1984), bees do not choose the pollen they collect only according to its quality; the harvest of this material is generally subordinate to nectar sugar content and its abundance. According to Bertrand (1967), the bees harvest preferably those which contain 40 to 50% of sugar, and from one day to another they remember what time a flowers reaches its most favorable concentration.

CONCLUSIONS

Pollen forms varied in frequency and abundance probably due to an abundance of geographical distribution of the plant and the effect of environmental conditions on nectar production. For the identification of pollen types and the interpretation of pollen taxa, extensive experience, the establishment of the phytogeographic map and the pollen Atlas from our country are essential.

REFERENCES

Ayansola A.A., Davies B.A. (2012). Honeybee Floral Resources in Southwestern Nigeria. Journal of Biology and Life Science, 3 (1), pp. 127-139.

Benaziza-Bouchema D., Schweitzer P. (2010). Caractérisation des principaux miels des régions du Nord de l'Algérie. Cahiers d'Agriculture, 19 (6), pp. 432-438.

Bertrand E., (1967). La conduite du rucher, ed., Librairie Payot Lausanne

Chefrour A., Draiaia R., Tahar A., Ait Kaki Y., Bennadja S., Battesti MJ.,(2009). Physicochemical characteristics and pollen spectrum of some North-East Algerian honeys. African journal of food, agriculture, nutrition and developpement, 9(5): 1276- 1293

Corvucci F., Nobili L., Melucci D., Grillenzoni F.V (2015). The discrimination of honey origin using melissopalynology and Raman spectroscopy techniques coupled with multivariate analysis. Food chemistry, 69: 297-304.

Darrigol J. L., (1979). Le miel pour votre santé. Ed Dongles, 139 p

Dukku U.H., (2013). Identification of plants visited by the honeybee, *Apis mellifera* L. in the Sudan Savanna zone of northeastern Nigeria. African Journal of Plant Science, 7(7): 273-284.

Feller. M.J (1979) : Analyse pollinique des miels du Quebec. Apidologie 10(4): 313-340.

Gadbin C. (1980) : Les plantes utilisées par les abeilles au Tchad méridional. Apidologie 11(2) : 217-254.

Iritie B.M., Wandan E.N., Armand A., Paraiso A.A., Fantodji A, Gbomene L.L. (2014). Identification des plantes mellifères de la zone agroforestière de l'école supérieure agronomique de yamoussoukro (côte d'ivoire). European scientific journal, 10 (30) : 444- 458

Kaya Z., Binzet R., Orcan N. (2005): Pollen analyses of honeys from some regions in Turkey. Apiacta 40: 10-15.

Louveaux J., Maurizio A., Vorwhol G. (1970). Commission Internationale de Botanique apicole de l'UISB : Les méthodes de la mélissopalynologie. Apidologie. 1(2) : 211-227.

Louveaux. J (1977)**:** Atlas photomicroscopique d'analyse pollinique des miels. 132p

Louveaux J., Abed. L. (1984). Les miels d'Afrique du nord et leur spectre pollinique. Apidologie, 15 (2): 145-170.

Louveaux. J (1985) . Les abeilles et leur élevage. Ed. Hachette, Paris.

Makhloufi C., Kerkvliet J.D. , D'Albore G.R., Choukri A., Samar R. (2010). Characterization of Algerian honeys by palynological and physico-chemical methods. Apidologie. 41: 509–521.

Oddo L., Piazza MG., Sabatini A., Accorti M. (1995): Characterization of unifloral honeys. Apidologie 26: 453-465.

Ouchemoukh S., Louaileche H., Schweitzer P. (2007). Physicochemical characteristics and pollen spectrum of some Algerian honeys. Food Control; 18: 52-58.

Rabiet E. (1984). Plantes mellifères, plantes apicoles, Rapports entre les plantes et l'abeille domestique. Ed. E.Rabiet .

Radev Z.(2018). The impact of different protein content of pollen on honey bee (*Apis mellifera* L) development. American journal of entomology. 2 (3): 23-27.

Sajwani A.,Farooq S.A., Patzelt A.,Eltayeb E.A., Bryant V.M. (2007). Melissopalynological Studies from Oman. Palynology, 31: 63-79.

Saury. A (1981). Plantes mellifères. L'abeille et ses produits. 2ème partie:cinquante plantes mellifères pp 16-135. Ed LE Chevalier.

Sawyer R. (2010). Honey identification. Cardiff academic press. 115 p.

Seijo M C., Aira M J., Mendez J., (2003). Palynological differences in the pollen content of *Eucalyptus* honey from Australia, Portugal and Spain. Grana, 42: 183-190.

Terrab A., Valdes B., Diez M. J. (2001). Pollen analysis of honeys from the Gharb region (NW Morocco). Grana 40: 210-216.

Valencia-Barrera R.M., Fombella-Blanco M.A., Fernandez-Gonzalez D., Diaz-Gonzalez T. E.(1994). Les Spectres Polliniques des Miels de différentes régions Phytogéographiques de la Province de León (N.O. de l'Espagne). Grana 33: 268-275.

Von Der Ohe W., Persano Oddo L., Piana ML., Morlot M., Martin P. (2004): Harmonized methods of melissopalynology. Apidologie 35: 18-25.

INDEX OF AUTHORS

INSTRUCTIONS FOR AUTHORS

AGROFOR International Journal publishes scientific and expert papers on agriculture, rural development, environmental protection and management of natural resources, animal husbandry and veterinary medicine, forestry, and biology. It is the endeavor of the Journal to give place to papers of high scientific quality and international interest, authored by international scientist in order to stimulate contacts and exchange of knowledge fostering scientific productivity

Manuscripts, submitted via electronic journal web system should be prepared in Microsoft Word **(Times New Roman font, 11 pt)** and submitted in format 17 x 24 cm **(File / Page setup / Paper / Width = 17 cm; Height = 24 cm)**, with single line spacing **(Format / Paragraph / Line spacing = Single)**, 2 cm margins all around **(File / Page setup / Margins / Top = 2 cm; Bottom = 2 cm; Left = 2 cm; Right = 2 cm)**, that is approximately 44 lines per page in this format. All technical details are available also on AGROFOR Internatinal Journal website: http://www.agrofor.rs.ba/page.php?id=8

Manuscripts are published in English. Papers that have been published elsewhere, in whole or extracts (excerpts) of their important findings, will not be accepted. A manuscript should not exceed 10 pages. Exceptions can be made if content and quality of the paper justify it (at the discretion of the Editor).

Full research papers should include the following sections:

- Title and author/s name/s

The author/s name/s should be placed below the title with affiliations. Author/s affiliation should indicate name and address of institution, including the e-mail address of the corresponding author. Title should provide a concise but also an informative synthesis of the study (recommended not more than 100 characters including spaces). Ensure that the title contains the most important words that relate to the topic.

- Abstract

The summary, in English language, should provide basic data on the problem that was treated and the results obtained. It should be brief, preferably one paragraph only, up to 250 words, but sufficient to inform the reader of the character of the work, its results and its conclusions.

- Key words

Keywords should provide 4-6 words or compound words, suitable for an information retrieval system. Choose the appropriate keywords and phrases for your article. Think of a phrase of 2-4 words that a researcher might search on to find your article. Repeat your keywords and phrases 3-4 times throughout the abstract in a natural, contextual way.

- INTRODUCTION

The introduction should answer the questions what was studied, why was it an important question, what was known about it before and how the study will advance our knowledge.

- MATERIAL AND METHODS

Material and methods explain how the study was carried: the organism(s) studied; description of the study site, including the significant physical and biological features, and the precise location (latitude and longitude, map, etc); the experimental or sampling design; the protocol for collecting data; how the data were analyzed. In this section also should be provided a clear description of instruments and equipment, machines, devices, chemicals, diagnostic kits, plants/animals studied, technology of growing/housing, sampling sites, software used, etc.

- RESULTS and **DISCUSSION**

Results and Discussion should be combined into a single section.

The results objectively present key results, without interpretation, in an orderly and logical sequence using both text and illustrative materials (tables and figures).

The discussion interpret results in light of what was already known about the subject of the investigation, and explain new understanding of the problem after taking results into consideration.

The International System of Units (SI) should be used.

- CONCLUSIONS

The conclusion should present a clear and concise review of experiments and results obtained, with possible reference to the enclosures.

- ACKNOWLEDGMENTS

If received significant help in designing, or carrying out the work, or received materials from someone who did a favour by supplying them, their assistance must be acknowledged. Acknowledgments are always brief and never flowery.

- REFERENCES (LITERATURE)

References should cover all papers cited in the text. The in-text citation format should be as follows: for one author (Karaman, 2011), for two authors (Erjavec and Volk, 2011) and for more than two authors (Rednak *et al*., 2007). Use semicolon (Rednak *et al*., 2012; Erjavec and Volk, 2011) to separate multiple citations. Multiple citations should be ordered chronologically. The literature section gives an alphabetical listing (by first author's last name) of the references. Please see "INSTRUCTIONS FOR AUTHORS" / Bibliographic style on the web page of the Journal for more details: http://www.agrofor.rs.ba/page.php?id=8

Short communication should include the following sections: Title, Abstract, Key words, Main text, Acknowledgments, References, Tables and Figures with captions.

SUPPLY OF ARTWORK, PHOTOS: Diagrams and graphs should be provided as finished black and white line artwork or colour images. Electronic graphics included in your manuscript should be either inserted in the word document or as .gif or .jpg formats. Please check with the editor if you wish to submit any other type of graphic for conversion suitability. Photos should be supplied un-screened in original form or in electronic form. All illustration (diagrams, graphs, tables, photos) must be fully captioned. When there are a number of illustrations, the author should endeavour to reduce the amount of text to accommodate the illustrations in the limited space available for any article.

THE REVIEW PROCESS: Submitted manuscripts are reviewed anonymously by 2 international referees (duble blind review). All tracking of manuscripts and reviewers is done by the Editor. All attempts will be made to ensure review process done within three months after the submission. Manuscripts will be returned to the coresponding authors when each review is completed.


Agrofor