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SOLVING THE PROBLEM OF CONTAMINATING SMOKED FOOD WITH CARCINOGENIC COMPOUNDS OF SMOKE

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ABSTRACT

Meat and fish smoked products, widely produced nowadays, occupy a permanent place in the mass diet. The consumption of smoked meat is estimated by FAO at 15.6 million tons in 2019 (+40 % growth over the past ten years). This is due to the increased incomes of consumers in many countries, which made meat and fish smoked products, once classified as "premium" delicacies, more accessible to the majority. There has been a shortage of high-quality raw materials, which, combined with a highly competitive food market, forces manufacturers to reduce their costs by using non-traditional raw materials. The latter leads to increased use of processing raw materials with smoke to effectively mask individual defects in taste, appearance and consistency of products. As a result, there is a carcinogenic contamination problem because of polyaromatic hydrocarbons (PAHs) presented in the smoke and smoking liquids, and the growth of cancer. PAHs are formed as a result of pyrolysis of wood during smoke generation at temperatures above 450-480 °C. Currently used smoke generators and schemes for cleaning smoke from PAHs are not effective enough, so they do not eliminate the main cause of PAH formation, uncontrolled pyrolysis. The principal solution to the problem is to develop methods and equipment for producing smoke at temperatures below carcinogenic peaks. A successful solution is the method for producing smoke with an infrared power supply, implemented in the design of IR smoke generator (IR-SG). The device allows to reliably maintain the pyrolysis temperature of wood below 450 °C. The effectiveness of the method and apparatus is confirmed by studies of products smoked with IR-SG, in which the content of Benzo(a)pyrene is less than 0.0002 mcg/kg, which is lower than the maximum permissible concentrations of this compound in food.

Keywords: *Smoked products, carcinogenic compounds, smoke generation, infrared smoke generator.*

INTRODUCTION

Smoking is the oldest method of processing meat and fish, which gave the opportunity to improve the taste of the food and preserve it reliably and for a long time. Meat and fish smoked products rich in protein are produced today in a wide

range and different prices, so they occupy a permanent place in the diet of modern people. The consumption of smoked meat is estimated by the FAO in 2019 at 15.6 million tons, with an increase of 40% over the past ten years. The smoked meat industry today is highly fragmented, with producers located in North America with a share of 32.92% of global production, and in Europe. The world leader in the production of smoked food is WH Group, with a global market share of 10.18% in 2015 (IndustryResearch, 2020).

The preserving factors during smoking are dehydration of the product to a residual mass fraction of water no more than 40% of the total weight (cold smoking method) and high temperature from 60 to 120 °C (hot smoking method). In both methods, the raw materials are also affected by chemical preservatives in the smoke – phenols and carbonyl compounds. Phenols act as powerful antioxidants and antiseptics, to a lesser extent, forming organoleptic signs of smoking, while carbonyl compounds are mainly responsible for the formation of taste, aroma and color of the smoked meat and have a weak bactericidal effect. In total, the smoke contains more than 10,000 organic compounds which are products of incomplete combustion of wood components such as cellulose, hemicellulose and lignin, including acids, alcohols, and esters. (Kurko, 1960).

The absolute negative effect of smoking is the contamination of products with pro-carcinogenic and carcinogenic compounds – polyaromatic hydrocarbons (PAHs) of the 3,4-Benz(a)pyrene type, as well as nitrosamines (NA). PAHs are formed as a result of pyrolysis of wood during the smoke generation at temperatures above 450-480°C (Kim, 2004).

Despite the high level of carcinogenic hazard (Rozentale *et al*., 2018), the enhanced taste of smoked products makes them a common and affordable delicacy these days. The shortage of high-quality raw materials, combined with a highly competitive food market, forces manufacturers to reduce their costs by using non-traditional raw materials, or the materials with reduced commodity characteristics. The latter leads to an increasing use of Smoking to effectively mask certain defects in taste, appearance and consistency of products. Increased consumer incomes in many countries have made meat and fish smoked products, in the recent past classified as premium delicacies, more accessible. This is confirmed by the steady growth in the consumption of smoked products, shown in the diagram in figure 1 (FAO, 2018).

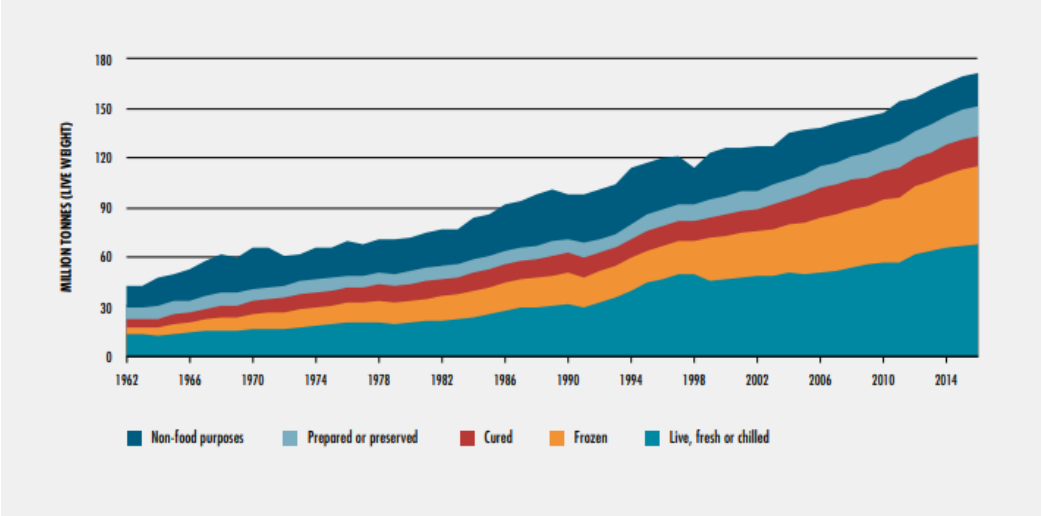

Figure 1. Utilization of world fisheries production, 1962–2016

The global smoked meat market is estimated at $34,660 million in 2020 and is expected to reach $39,330 million by the end of 2026, increasing by an average of 1.8% during 2021-2026. The main regions of consumption of meat and fish smoked products today are North America, Europe, China and Japan (IndustryResearch, 2020).

As a result, there is a problem of contamination of mass-consumption food with carcinogens (PAHs) in the composition of smoke or smoking liquids and a potential significant increase in cancer diseases. Currently used smoke generators and schemes for cleaning smoke from PAHs are not effective enough, so they do not eliminate the main cause of PAH formation – uncontrolled pyrolysis (Shokin *et al*., 2020).

The objective of the present paper is to provide an overview of the effective solution of this problem with a special focus on the development of new methods of smoke generation and smoke generators, which reliably maintain the pyrolysis temperature below carcinogenic peaks.

MATERIAL AND METHODS

The article is based on an extended review of secondary and primary data collected from the scientific and technical publications and patent search, as well as during experiments conducted in the winter of 2019-2020 at the research laboratory of the Department of Food Production Technologies of Murmansk State Technical University and at the University's educational and experimental workshop. In the process of IR smoke generation, the distribution of temperature and moisture content in the fuel layer (sawdust of deciduous trees with bulk density from 84 to 154 kg/m^3 with an initial humidity of 45 to 60 %), for which the temperature T (K) and relative humidity U (% или kg/m^3) were measured at various points of

layer with a coordinate x (m). The layer had a constant irradiated surface area S (m^2) in all experiments, which was provided by the design features of the IR smoke generator. The coordinate x characterizes the position of the measurement point in the height of the layer as the distance from the irradiated surface, measured by the normal passing through the measurement point deep into the layer. The thickness of the layer corresponds to the distance measured by the normal between the plane of the irradiated surface of the sawdust layer and the plane of the sawdust layer farthest from it (it varied from 0.005 m to 0.12 m). In all experiments, free filling of sawdust (without pressing) is used, which forms a layer of fuel of the final thickness as a porous layer containing solid wood particles, moisture condensate and moist air with a high content of water vapor. To determine the moisture content of sawdust, a standard weight method was used – a sample of sawdust weighing from 1 to 3 g, taken point-by-point directly from the sawdust layer at the measurement point, was dried in a drying chamber at 105 °C to a constant mass. The temperature of the fuel layer was determined using calibrated needle thermocouples with measuring ranges from minus 50 to 1200 °C (measurement accuracy (±0.1 °C)) placed directly at the measurement point. All experiments were performed at least three times over. Mathematical processing of the experiment results was carried out using generally accepted methods of mathematical statistics. Measurements of fuel temperature and humidity were performed both before and during smoke generation. The technical capability of measurements directly in the process of smoke generation was provided by the design features of the pilot model. Temperature measurement of the pyrolysis of wood during the IR smoke generation was performed according to the developed original method (Shokina et al., 2019), which provides for production of model of wood specimen geometry which corresponds to the porous structure of the layer of sawdust a given bulk density. For correct measurements, the model sample had an initial humidity corresponding to that of the sawdust layer. A needle-shaped thermocouple was placed in the model sample, for which it was technically possible to take readings continuously during the entire process of thermal decomposition of the model sample under the influence of IR radiation in the smoke generator. The carcinogenic safety of smoke from an IR smoke generator was determined indirectly based on the results of determining the mass fraction of 3,4-Benz(a)pyrene in smoked fish fillets made according to the traditional scheme of cold smoking. For the study, a standard method was used based on the extraction of Benz(a)pyrene by hexane from a product pretreated with an alcoholic solution of caustic potassium, the separation of a fraction of polycyclic hydrocarbons by thin-layer chromatography on aluminum oxide, and the quantitative determination of the resulting fraction of Benz(a)pyrene by low-temperature spectrofluorometry. The range of determined values of the mass fraction of Benz(a)pyrene in the analyzed products by this method is from 0.0002 to 0.005 mg/kg.

RESULTS AND DISCUSSION

The analysis of Russian smoke generator designs has shown the predominance of endothermic devices with internal heat generation (more than 70% of the total number of operated devices and devices presented on the smoking equipment market). Wood fuel is heated in these devices by partial inflaming. Endothermic smoke generators are characterized by frequent fuel firing, uncontrolled temperature growth in local areas up to 800-1200°C, and, as a result, by high contamination of PAH smoke. Analysis of exothermic smoke generators (with external heat generation) showed common technical characteristics: a simple design, a primitive system of water extinguishing of open flames, the absence of any mechanization of the process, the absence of automatic monitoring and control. In general, most of the devices for producing smoke of both types can be characterized as obsolete (Shokin *et al*., 2020).

Imported exothermic smoke generators, currently available on the Russian market, are more competitive than domestic ones due to numerous options that allow to:

- prevent the occurrence of hot spots of fuel overheating during the smoke generation process;
- monitor and control (automatically) important technological parameters of smoke-relative humidity, temperature, air-weight concentration;
- reduce energy and wood fuel consumption per unit of finished product;
- effectively clean up smoke emissions into the atmosphere.

The most widely used in Russian meat and fish enterprises are smoke generators of the SUPER SMOKE type by VERINOX, chip smoke generators by AUTOTERM, smoke generators by REICH and VEMAG that differ slightly in design (Shokin *et al*., 2020).

The advantage of foreign manufacturers of smoke generators is to offer consumers, as a rule, a whole product line of devices. This provides consumers with a wide range of equipment designs, depending on the purpose of processing food raw materials and capabilities. For example, there are product lines of smoke generators from German and Polish companies "FESSMAN", "Schröter" or "FEMAG", in which the choice is given between a smoldering smoke generator (RATIO-TOP), a friction smoke generator (RATIO-FRICTION) and a liquid one (RATIO-LIQUID). The disadvantage inherent in most foreign and Russian smoke generators up to date is the lack of automatic control of the temperature of wood pyrolysis, which leads to a high risk of spoiling the smoke with PAH.

The Department of Food Production Technologies of Murmansk State Technical University has developed a method for producing smoke using infrared energy supply to wood material (Shokin *et al*., 2020).

In thee IR smoke generator, a layer of wood sawdust with a moisture content of 45 to 60% and a bulk density of 104 to 154 kg/m^3 is irradiated with infrared rays (the radiation wavelength ranges from 3.5 to 5.5 microns, the distance from the fuel surface to the wood is from 0.08 to 0.10 m). The amount of energy supplied to the sawdust layer is consistent with the kinetics of wood heating.

As it was found, the kinetics of heating the fuel layer is mainly affected by the bulk density of sawdust and their moisture content. These parameters affect the absorption, transmission, and reflectivity of the fuel layer, which determine the amount of absorbed radiant energy. Controlling the moisture content of the fuel directly during the smoke generation process, as well as correctly accounting for its specific surface area, allows to reliably manage the pyrolysis temperature and maintain it in the desired range. This, in turn, minimizes the risk of PAH formation. The main technical parameters of the IR smoke generator in comparison with other smoke generators, widely represented in meat and fish enterprises in Russia, are shown in table 1.

The data presented below shows that the IR SG has a number of competitive advantages over other SGs due to its ability to manage the process of producing smoke at a stable temperature, and guaranteed high carcinogenic safety of the resulting smoked products.

Table 1. Technical and economical characteristics of the IR smoke generator.

Feature	Content	Comparison with analogs
Pyrolysis temperature, ºC	from 350 to 400	Operating modes guarantee stable temperature maintenance in the specified range throughout the pyrolysis process, unlike most other devices
Sawdust consumption, kg/m^3 of process smoke	no more than 4,5	Less on average by 50% compared to other devices
Electric power consumption, kW per hour	from 2,75 to 8, 25	Less with comparable performance by 40-100% compared to other devices
Performance, m^3 of smoke per hour	no less than 43,5	Comparable to the performance of other devices with lower fuel consumption
Productivity, tons of cold-smoked finished products per day	up to 1,0	-
Mass fraction of 3,4-Benz (a)pyrene, mcg per 1 kg of cold-smoked finished products	less than 0,0002	Significantly lower than the maximum permissible concentrations in Russia and the European Union

*Source: Author's elaboration based on the personally conducted experiments and on the review of scientific and technical publications and patent search.

The problem of computer simulation of the smoke generation process is also very relevant. The mathematical model can be used as the basis for automated calculation of the pyrolysis temperature, which is the main parameter that determines the carcinogenic safety of smoke.

On the basis of the known differential equations of heat and mass transfer and the experiments carried out, a description of the processes of mass and heat transfer during pyrolysis of fuel in a smoke generator with an IR power supply is proposed in the form of a system of differential equations (Shokin *et al*., 2020):

$$\begin{cases} C \cdot \rho \cdot \dfrac{\partial T}{\partial \tau} = \lambda \cdot \dfrac{\partial^2 T}{\partial x^2} + r \cdot \alpha \cdot \dfrac{\partial U}{\partial \tau} + w(x) + q(x) \\ \dfrac{\partial U}{\partial \tau} = D_u \cdot \dfrac{\partial^2 U}{\partial x^2} + D_t \cdot \dfrac{\partial^2 T}{\partial x^2} \end{cases}, \quad (1)$$

where $C \cdot \rho = c_W \cdot \dfrac{U \cdot \rho_{SD}}{1-U} + c_{SD} \cdot \rho_{SD}$ – volume heat capacity of the water-sawdust mix, j/(m^3·K) ($c_{SD.}, c_W, \rho_{SD}$ – specific heat capacities of dry sawdust (*SD*) and water (*W*), j/(kg·K), and the density of sawdust, kg/m^3, the heat capacity of steam is neglected; U – humidity of sawdust, unit fractions);

T – temperature of sawdust, K;

τ – duration, seconds;

λ – the coefficient of thermal conductivity of the wood sawdust layer, set by the specific surface of sawdust and its moisture content, W/(m·K);

r – latent heat of vaporization, j/kg;

α – the coefficient that determines the percentage of participation of condensation and vaporization processes in the volume of the layer, unit fractions;

U – moisture content of sawdust, kg/m^3;

$w(x)$ – volumetric heat absorption in the sawdust layer with a coordinate x, that is counted from the lower border of the sawdust towards the IR emitter, W/m^3;

D_U – the coefficient of potential conductivity of moisture transfer, characterizes the transfer of moisture in the fuel layer due to capillary phenomena and moisture adsorption on the surface of sawdust, m^2/seconds;

D_t – the coefficient of thermal and water transfer potential conductivity in the sawdust layer, (kg/(K·m·seconds);

$q(x)$ – heat of thermal decomposition of wood in the volume of the layer, W/m^3.

It follows from the equations that the IR smoke generation process is a complex heat and mass transfer process. Pyrolysis of wood with the formation of smoke occurs in a thin (thickness from 1 to 3 mm) surface layer of fuel, which directly absorbs infrared radiation. This process is a phase transition and is accompanied by the release of heat, which forms its internal source in the fuel layer. Moisture and heat move in the sawdust layer by several mechanisms simultaneously. The radiant stream, partially absorbed by a thin surface layer of wood fuel (with a moisture content of 40 to 55%), forms a large temperature gradient. Under the influence of this gradient, heat moves deeper into the layer by the mechanism of thermal conductivity. Under the influence of the difference in moisture content of the lower layer and the dry surface layer, moisture moves in the layer by the mechanism of moisture conductivity. The third mechanism is the convection moisture exchange in the air layers presented in the sawdust layer (formed by large voids between the particles). Moisture transfer in the fuel layer maintains a stable temperature of the smoke-generating layer.

Equation (1) is solved for the given boundary and initial conditions using a numerical method (the grid method, specifically). The values of thermal coefficients (coefficient of thermal conductivity, volumetric heat capacity), coefficients of the differential equation (potential conductivity of moisture transfer and heat transfer) are obtained by solving the inverse problem and calculating. The computer program is written for predicting the temperature at any point in the fuel layer at any time of smoke generation. When developing the program, the thickness of the elementary fuel layer in which pyrolysis occurs directly (from 1 to 3 mm) is taken into account.

When comparing the results of modeling the kinetics of fuel heating with experimental data (figure 2), a satisfactory convergence and an admissible error were found.

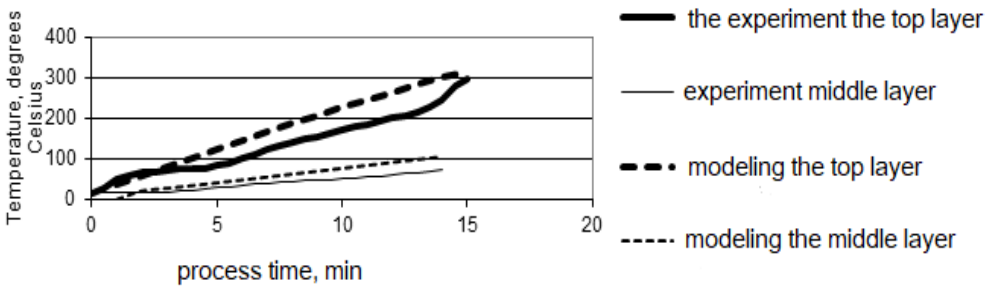

Figure 2. Fuel heating kinetic curves by layer thickness: bulk density of sawdust – 118 kg/m^3, moisture content of sawdust – 35%, the amount of moisture added in the process – 40% of the fuel mass

CONCLUSIONS

The consumption of smoked meat and fish is growing in the world, which is a potential threat to the growth of cancer diseases in the population of advanced and emerging countries. In the coming years, the problem of increasing the carcinogenic safety of smoked meat and fish will be extremely relevant. The most effective solution to the problem is to develop innovative methods of smoke generation and their hardware design.

An example of a successful solution to the problem is a smoke generator with an infrared power supply. The device design allows to reliably control the pyrolysis temperature of wood fuel (sawdust with a bulk density of 104 to 154 kg/m^3 and a moisture content of 40 to 60%) by supplying heat energy in an amount consistent with the kinetics of wood heating. A mathematical model of the IR smoke generation process has been developed, which is the basis of a computer program for predicting the temperature of fuel pyrolysis. The stability of the pyrolysis temperature in the IR smoke generator is confirmed by studies of the content of 3,4-Benz(a)pyrene in smoked mackerel fillets, made with the use of the IR-generated smoke.

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ANALYSIS OF MORPHOMETRIC PARAMETERS DUCK EGGS OF LOCAL BREED SHAOXING

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ABSTRACT

The efficiency of industrial poultry farming within the optimization of poultry technology, depends on the level of genetic potential of the flock. Selection features of Shaoxing ducks make this kind optimal for its breeding in the People's Republic of China. The study aims to evaluate the morphometric characteristics of Shaoxing duck eggs, which are bred on the breeding farm of Zhejiang Generation Biological Science and Technology Co., Ltd in Zhuji, Zhejiang Province, China. The weight, length, width of the eggs and the index of the egg shape have been determined. An individual method of counting the number of eggs laid by ducks of the Shaoxing breed for 4 adjacent months has been implemented. The average weight of the egg is 67.45 ± 0.22 g with limit values lim max = 89 g lim min = 45 g. The average value of egg length is 6.02 ± 0.01 cm, width – 4.45 ± 0.01 cm. The duck egg shape index is 74.01 ± 0.12. Thereby systematic individual studies of morphometric parameters of eggs will increase the effect of selection by expanding the indicators of lifelong assessment of the uterine population of ducks. Selection of queens for the breeding core of the breed according to the indicators of manufacturability of morphometric parameters of eggs will increase the incubation yield of ducklings and, accordingly, will be one of the effective mechanisms to ensure economic profitability of breeding Shaoxing ducks.

Keywords: *Duck, eggs, weight, genetic potential, breed*

INTRODUCTION

Traditional methods of breeding work with poultry breeds are effective due to the systematic assessment of the maximum number of parameters of economically useful traits. For ducks of the egg direction of productivity the factor of selection improvement of uterine livestock is the characteristic of morphometric indicators of eggs (Yuan *et al*., 2013). Individual registration and egg productivity analysis helps predict genetic trend in the population and the development and implementation of programs for the preservation of genetic resources of poultry (Zhang *et al*, 2019). Selection features of Shaoxing ducks make this kind optimal

for its breeding in the People's Republic of China. The profitability of its intensive industrial use directly depends on the incubation qualities of eggs and the intensity of their laying during the period of economic use of females (National Standard of China, 2012). The study population characteristics ducks specific breed groups in terms of the dynamics of change of weight and shapes depending on the period egg laying is part of long-term monitoring organization to streamline playback, increased phenotypic manifestation of the genetic potential productivity and management system targeted breeding poultry and receiving products.

That is why the purpose of this study was to evaluate the morphological characteristics of ducks' eggs of Shaoxing breed.

MATERIALS AND METHODS

Research has been conducted in 2019 at a duck farm of Zhejiang Generation Biological Science and Technology Co., Ltd in Zhuji, Zhejiang Province, China. For experiments were used 329 ducks, which were kept under identical feeding conditions in one poultry house. Duck egg production was determined for 4 months (April, May, June, July). The experiment took into account the age of laying the first egg (days). Morphometric parameters of 838 duck eggs were evaluated for 3 days at the age of 48–52 weeks by weight (g), length and width (cm). The length (L) and width (W) of eggs were measured with an accuracy of 0,1 mm by caliper. Weighing of eggs was carried out on electronic scales JM-A 20001 with an accuracy of 0,1 g. The egg shape index was calculated using the formula:

ESI = (W / L) * 100 (Reddy *et al*, 2014)

The biometric processing of experimental data was conducted in accordance with generally accepted techniques. The arithmetic mean value, the error of the mean, the correlation coefficient and the coefficient of variation were calculated.

RESULTS AND DISCUSSION

Research egg productivity demolished by the number of eggs in my time allows, along with individual evaluation of breeding stock to analyze the effectiveness of economic use of birds in a particular herd. According to the obtained results (Fig. 1), the total egg production in the studied group of ducks was 37629 eggs for 4 months. The average number of eggs laid per female ranged from 27.5 in July to 29.9 in May. The highest peak of egg productivity was observed in May. In April and June, the average values for the month were 28.4 and 28.6 units, respectively. The decrease in the number of eggs laid in July is due to the maximum temperature and humidity. These features are confirmed in studies by other scientists (Biesiada-Drzazga *et al*, 2014.

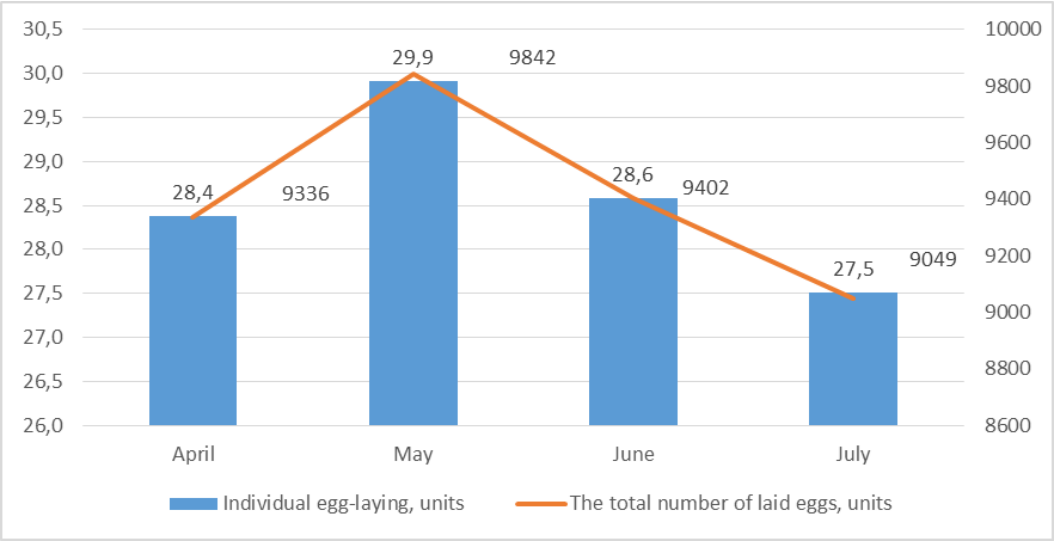

Fig. 1. Egg productivity of ducks depends on the month

The weight of eggs is one of the main indicators of technological suitability for incubation. From egg weight depends on the duration of the embryonic development of the fetus. According to the data presented in Table 1, the mass of eggs ducks breed Shaoxing ranged from 45 g to 89 g. The average weight was 67.95 g, which is consistent with the data of the Bureau of Product Quality (Zhuji, China), according to which the average weight of a duck egg should be 6 – 68 g (National Standard of China, 2012). The coefficient of variation of egg mass was 9.27%. The weight of duck eggs can vary depending on the season. In research, scientists have shown an increase in the weight of eggs of Shaoxing ducks in the period from September to December (Chepiha, A. M. *et al*, 2017a).

Table 1. Average indicators of weight, size, and shape index of eggs in the Shaoxing breed ducks

Trait	Mean ±Sd	Lim Min-Max	Cv, %	Standard of breed
Egg weight, g	67.95±0.22	45–89	9.27	62-68
Long length of egg, cm	6.02±0.01	5.1–6.8	4.28	–
Short length of egg, cm	4.45±0.01	3.9–4.9	3.53	–
ESI, %	74.01±0.12	59.7–88.2	4.54	72–76
Age of laying the first egg, days	146.5±0.94	112–194	11.68	130–140

Indicators of egg measurements in addition to the individual characteristics of the egg productivity of females is one of the basic criteria for predicting the efficiency of incubation and the volume of industrial production of genetic resources of ducks. In studies of altitude and latitudinal measurements, the average value of egg length was set at 6.02 cm with limits of 5.1 – 6.8 cm. The width of the eggs of

ducks of the studied breed Shaoxing was on average 4.45 cm and was in the range of 3.9 – 4.9 cm. The egg shape index ranged from 59.7 to 88.2% and averaged 74.01%. The relationship between length and width reflects the proportionality of the eggs, which is due to the individual structure of the oviduct. In similar studies index of egg shape of Shaoxing ducks was 74.8 – 75.5 and depended on the color of the shell (Chepiha, A. M. *et al*, 2017a). In studies by other authors features of elongation of eggs of chickens with age of females are noted (Nedeljka Nikolova *et al*, 2006).

Calculation of the correlation coefficient revealed a direct reliable relationship of mean strength with a value of 0.331 ± 0.031 ($p < 0.0001$) between the length and width of the eggs, which indicates the effective direction of selective selection of uterine livestock to form the main nucleus of the herd. The age of puberty, along with the characteristics of reproductive ability determines the individual characteristics of the term of economic use of females. In the study group of ducks, the average age of demolition of the first was 146.5 days. The limits of the values of this indicator were in the range of 112–194 days.

CONCLUSION

Thus, according to the results of monitoring the egg productivity of ducks of all ages of the Shaoxing breed on a typical farm in Zhuji China it can be concluded that the revealed features of egg-laying of the studied females characterize the monthly cyclicity of egg laying. During the studied months, one female has an average of 27.5 pieces to 29.9 pieces, which is within the performance parameters of the breed, which are defined by its standard. The evaluation of technological characteristics of the eggs, the parameters defined medium weight and shape index correspond to the breed standard and ensure the effectiveness of the process of incubation.

Further research should focus on studying the polymorphism of the Shaoxing duck population by genes associated with productivity indicators, which will increase the efficiency of genetic resource management while maintaining the optimal level of biological diversity in the breed.

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PHYLOGENETIC ANALYSIS OF UKRAINIAN ISOLATE OF *RASPBERRY LEAF BLOTCH VIRUS*

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ABSTRACT

Raspberry leaf blotch virus (RLBV) is a new member of the *Emaravirus* genus (*Fimoviridae*, *Bunyavirales*). Representatives of this family are characterized by a segmented "-" RNA genome, helical nucleocapsid and enveloped spherical or pleomorphic virions 80-120nm in diameter. Transmission of these viruses is carried out by eriophyid mites. The virus is widely distributed in Europe. In this paper, the phylogenetic relationships between the Ukrainian RLBV isolate and isolates from the other countries from the GenBank database were investigated. Samples of symptomatic raspberry plants were selected for the work. Total RNA was isolated and RT-PCR was performed using primers to the region of the nucleocapsid protein (P3) gene. The resulting amplicon with a length of about 500bp was sequenced. Sequences were analyzed using BLAST and MEGA7 programs. As a result of BLAST analysis, it was shown that the Ukrainian isolate of RLBV has a high similarity to some Finnish, British, Serbian and Slovak isolates (93-99% similarity). Nevertheless, the dendrogram constructed in MEGA7 did not distribute these isolates in a separate cluster. Interestingly, sequences of isolates from Finland, Britain, and the Balkans were segregated into different parts of the phylogenetic tree. This pattern can be explained by the low divergence of the virus population or small number of isolates in the database.

Keywords: *Raspberry leaf blotch emaravirus, raspberry, Ukraine.*

INTRODUCTION

Raspberry leaf blotch virus (RLBV) is a novel member of the *Emaravirus* genus characterized with spherical or pleomorphic enveloped virions and segmented negative-sense RNA genome. There are 8 segments: RNA1 encodes an RNA-dependent RNA polymerase (RdRP), RNA2 –glycoproteins precursor (GPs), RNA3 – a nucleocapsid protein (NC), RNA4 – movement protein (Yu *et al*., 2013) and functions of the rest 4 related segments remain unclear (Lu *et al.*, 2015). RLBV is transmitted exclusively by Eriophyid mite *Phyllocoptes gracilis* and was initially described from raspberries as the pathogen associated with leaf blotch disorder (RLBD) in Great Britain (McGavin *et al.* 2012). This virus was also found in Finland (Bi *et. al.*, 2012), Bulgaria (Mavrič *et al.*, 2014), Poland (Cieslinska *et*

al, 2014), Montenegro (Zindović *et al.*, 2015), Serbia (Jevremovic *et al.*, 2019), Bosnia and Herzegovina (Delic *et al.*, 2020), France (Marais *et. al*, unpublished). The virus is considered to be a serious threat for raspberry plantations in Europe (Delić *et al.*, 2020). RLBV is the first emaravirus detected in Ukraine (Pozhylov *et al.*, 2018). In view of the growing export of Ukrainian raspberries (Ministry of Agrarian Policy and Food of Ukraine, 2018), economical importance of this fruit rises, increasing the neediness of raspberries' viral diseases study. The development of modern virology is closely linked to the use of molecular methods. Nowadays, it is possible to predict viral characteristics on the basis of already known data, using only information about its nucleotide or amino acid sequences. Thus, it can be said that the use of molecular phylogeny can be one of the most convenient tools for studying the epidemiological and biological properties of viruses that have recently been discovered. Polymerase chain reaction (PCR) is a rapid and convenient tool for detection of plant viruses (Uyeda and Masuta, 2015). In this paper molecular methods were used to detect RLBV on raspberries in Ukraine and investigate phylogenetic relationships of its novel Ukrainian isolate.

MATERIAL AND METHODS

In summer 2017, samples were collected from symptomatic raspberries from several locations in Kyiv city and Kyiv region (Ukraine). Total RNA was extracted using Ambition PureLink™ RNA mini kit (Invitrogen, USA) following the manufacturer's instructions. Then the samples were tested for RLBV by RT-PCR using primers pair 1287 (forward):5′-ATCCAGTAGTGAACTCC-3′and 1095(reverse):5′-CACCATCAGGAACTTGTAATGTTT-3′ (Lu *et al.*, 2015), which is specific to the nucleocapsid (NC) protein gene and targets a 570 bp fragment. Reverse-transcription was performed using 3 mcl of total RNA and RevertAid Reverse Transcriptase (Thermo Scientific, Lithuania) following the manufacturer's instructions. The PCR was performed using PCR Master Mix (Thermo Scientific, Lithuania) following the next procedure: denaturation at 73° for 5 min, 35 cycles at 95°C for 30 s, 56°C for 30 s, and 72°C for 45 s, and final extension at 72°C for 5 min. The products of total RNA extraction and PCR were checked by horizontal gel electrophoresis using 1,5% agarose (Ultrapure agarose Gibco BRL, Life Technologies, USA) in Tris-borate-EDTA buffer, and GeneRuler 1 kb DNA ladder (Thermo Scientific, Lithuania). RT-PCR products were purified using QIAquick Gel extraction kit (Qiagen, Germany), and then sequenced using Applied Biosystems 3730 x 1 DNA Analyzer. The resulting sequences were aligned using ClustalW and compared using BLAST analysis and Sequence Demarcation Tool Version 1.2 (SDTv1.2, Muhire *et al.*, 2014). Phylogenetic properties were elucidated using MEGA7 software (Kumar *et al*., 2016). Obtained plots and matrices were subsequently processed using Microsoft Windows XP Paint 6.1 (Microsoft, USA) and Origin 9 (OriginLab Corporation, USA).

RESULTS AND DISCUSSION

Several samples with symptoms of RLBD (wide chlorotic spots on the leafs, leaf deformation) were collected from Khmelnytskyi, Kyiv and Vinnytsia regions. RT-PCR using total RNA samples purified from symptomatic leafs (Figure 1A) has yielded positive results (Figure 1B). After wards the products were reamplified and prepared for the following sequencing. The product of expected size (about 500 bp) was sequenced and obtained sequence was deposited in the GenBank (MK123270.1). BLAST analysis of obtained 503 bp fragment of NC gene of RLBV showed its high identity to isolates from Bosnia and Herzegovina, Britain, Slovakia and especially identity to some isolates from Serbia and Finland (up to 99%). To compare our isolate with the others available from the GenBank, pairwise identity matrices were obtained using SDTv1.2. For higher readability and elimination of sequences with low coverage, only 18 isolates of 85 available from the GenBank are shown in the matrices. Initially, a phylogenetic tree of RLBV NC sequences available from the GenBank was built. For better topology and repeatability only 79 out of 85 were used in the mentioned tree. Sequences that represent each country in each branch of a dendrogram generated from 79 suitable for the analysis RLBV isolates were chosen for displayed phylogenetic tree. As expected, identity between amino acid sequences was much higher (Figure 2, the upper right corner) due to synonymous substitutions.

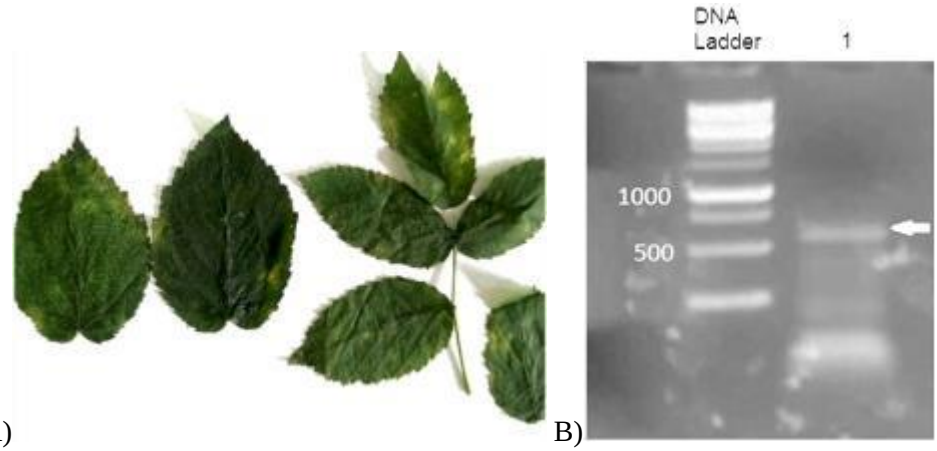

Figure 1: A) Symptomatic raspberries leafs. B) PCR product of 500+bp

The general appearance (two triangles separated with a single rectangle composed of different colors) of mentioned identity matrix (Figure 2, the lower left corner) indicated the presence of two groups of different sequences in our datasets.

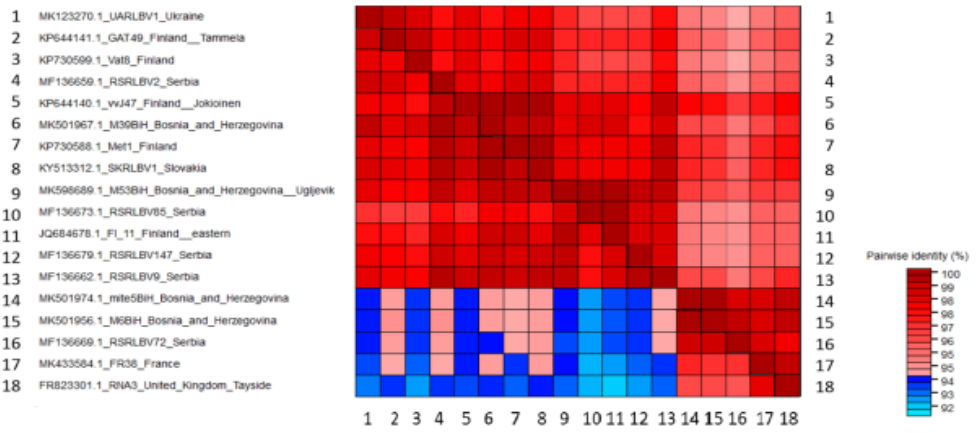

Figure 2: Color-coded pairwise identity matrices generated from 18selected RLBV sequences. Distance matrices obtained with SDTv1.2, and merged in MS Paint. The lower left corner: comparison of RLBV partial NC nucleotide sequences. The upper right corner: comparison of RLBV amino acid sequences translated from nucleotide sequences using MEGA7.

Also, pairwise identity frequency distribution plots were built to achieve a deeper insight into RLBV sequences identity. Comparison of a plot generated from 79 RLBV nucleotide sequences with a plot generated from 79 RLBV amino acid sequences showed that the first one had its main peak between 90 and 95% of pairwise identity (Figure 3, the black line), while the second one had its peaks after 95% of pairwise identity (Figure 3, the red line), which clearly proved our previous statement about higher identity of amino acid sequences. However, there were two peaks on both plots suggesting at least two clusters on phylogenetic tree generated from RLBV deduced amino acid sequences. To conclude, both plots showed high level of identity between isolate sequences.

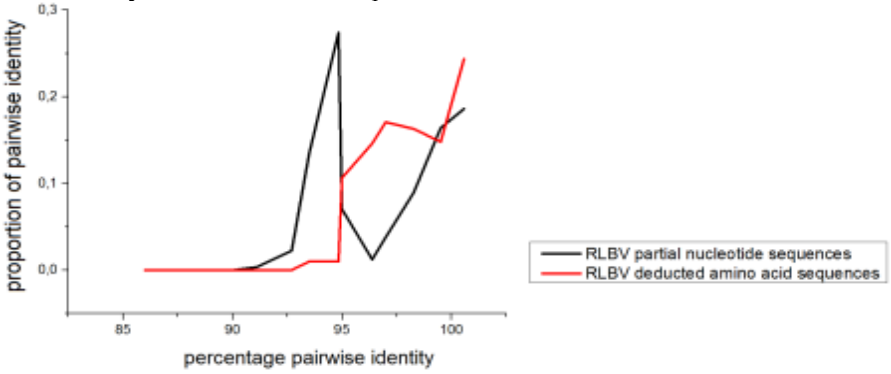

Figure 3:Pairwise identity frequency distribution plot generated from 79 RLBV partial nucleotide sequences and RLBV amino acid sequences, translated from partial NC nucleotide sequences using MEGA7. The initial data were obtained using SDTv1.2, and the plot was built using Origin 9.

Amino acid sequence-based dendrogram (Figure 4) shows division of isolates into two clusters, as predicted by the identity matrices and in accordance with previous studies (Jevremovic *et al*., 2019). Phylogenetic analysis showed the attribution of the Ukrainian RLBV isolate into cluster I. Also, there is a special clade in the cluster I formed by Ukrainian RLBV isolate and the most similar isolates from Finland, which may indicate common past events in virus evolution.

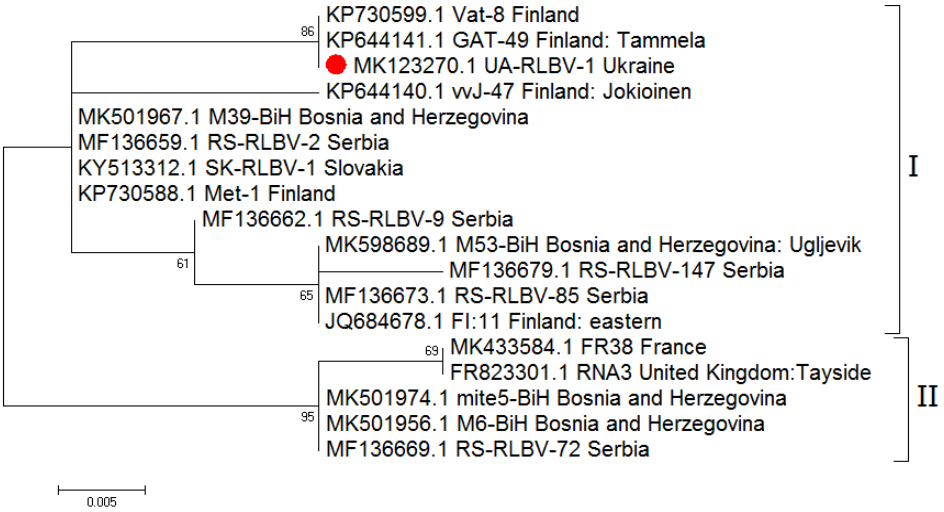

Figure 4: Phylogenetic analysis of 18 RLBV partial NC amino acid sequences, translated from partial NC nucleotide sequences using MEGA7. Ukrainian isolate is marked with a red dot. The analysis was performed with MEGA7 using Maximum Likelihood method. Bootstrap Replications – 1000. The percentage of trees in which the associated taxa clustered together is shown next to the branches. Bar represents branch lengths measured in the number of substitutions per site.

As expected, synonymous substitutions prevailed over non synonymous ones, leading to higher identity of amino acid sequences of the isolates as compared to their nucleotide sequences, which was in line with general concepts.

Segregation of isolates in two clusters wasn't related to their country of origin. It can be explained with the exchange of planting material between countries with following propagation of the virus by eriophyid mite. This can explain the presence of isolates with high identity (98,6–99,2%) in Ukraine and Finland, Serbia, Slovakia. Also, there was no significant difference between some isolates even from different clusters. Probably, there are not enough isolates in the GenBank and the whole picture of RLBV distribution in Europe remains unclear. It would be useful to have the sequences of other fragments of viral genome to know the number of the genome fragments because not every isolate contains all of them (in particular, RNAs 5-8) (Jevremovic *et al.*, 2019). Additionally, identity of RNAs 1-3 can be used as taxa demarcation criteria for members of order *Bunyavirales* (ICTV, 2020).

Sequences of all of genome fragments can be used to study reassortments, which can occur in emaraviruses (Patil *et al.*, 2017). As for now, it is difficult to reconstruct the pattern of RLBV spread between the countries. Our further research will include more regions of Ukraine and will bring us more information about distribution and diversity of RLBV, its impact on raspberry yield and probable ways of transfer through the country and abroad.

CONCLUSIONS

Ukrainian RLBV isolate was detected on a symptomatic raspberry plant using molecular methods, partially sequenced and deposited to the GenBank (accession number: MK123270.1). The analysis of RLBV nucleocapsid gene sequences revealed little differences between them that can be visualised with a pairwise identity matrix or a phylogenetic tree, which clustered a RLBV isolate from Ukraine with isolates from Slovakia and some isolates from Bosnia and Herzegovina, Finland and Serbia. The presence of RLBV isolates sequences from different countries in one cluster and sequences from one country in different clusters can be explained with high homogeneity of viral population due to natural properties of the virus and the vector or small number of sequences in the database and their short length. Still, future research needed to accumulate more sequences of this and other fragments of RLBV genome.

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POTENTIAL CONSTRAINT OF RAINFALL AVAILABILITY ON THE ESTABLISHMENT AND EXPANSION OF AGROFORESTRY IN THE MOPANI DISTRICT, LIMPOPO PROVINCE IN SOUTH AFRICA

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ABSTRACT

Agroforestry is a land use system that includes the use of woody perennial and agricultural crops and animals in combination to achieve beneficial ecological and economical interactions for food, fiber and livestock production. South Africa is considered a semi – arid country vulnerable to water stress, particularly drought. Limpopo Province average annual rainfall is 600mm and the threshold for rainfall agriculture is averaged at 250mm annually. In terms of forestry, rainfall needs to be higher than 750mm per annum to sustain commercial forestry. The objective of the study was to determine the potential constraint of rainwater on the establishment and expansion of agroforestry in Mopani district, Limpopo Province. A purposive sampling technique was used to select 62 agrosilviculture community growers and were spread on the 20ha SAFCOL forestland and each grower was allocated a row of 3226m^2 (1ha = 10000m^2; 20ha * 10000 = 200000m^2/62) for production. Quantitative and qualitative designs were used. The results were based on the month the data collection started: September 2019 rainfall results indicated that there was generally good rainfall (25 - 50mm) in the agroforestry sites as compared to the agricultural open field areas. October 2019 rainfall situation improved with an increase in rainfall (51 - 100mm). During November and December 2019, increasing rainfall was experienced at 100 - 200mm and 175 - 250mm, respectively. The last three rainfall status (33rd, median & 66th percentiles) indicated the estimates of rainfall in the future years. It estimated annual rainfalls at 601 and +1000mm; +1000mm & +1000mm across 33rd, 50th & 66th percentiles, respectively. This rainfall situation is well above the Limpopo Province annual average rainfall, agriculture and forestry thresholds. Currently, the eucalyptus trees

were integrated with other crops including maize, sweet potatoes, groundnuts and bambara nuts. It is thus recommended that the establishment and expansion of agroforestry be carried out in the identified suitable areas.

Key words: *Agrosilviculture System, Rainwater, Food Security, Limpopo Province and South Africa.*

INTRODUCTION

Results from several studies have indicated that agroforestry practices are perceived in different ways. According to (Lundgren and Raintree, 1982) agroforestry is viewed as the set of land-use practices, which involves the combination of trees, agricultural crops and/or animals on the same land management unit. Nair (1993) emphasized that although cultivating trees in combination with crops and livestock is considered an ancient practice, factors such as the deteriorating economic situation in many parts of the developing world, increased tropical deforestation; incorrect agricultural practices; degradation and scarcity of land because of population pressures; and growing interest in farming systems, intercropping and the environment have contributed to a rising interest in agroforestry since the 1970s. Based on the above mentioned factors (Mercer and Miller, 1998) further acknowledged that most research on agroforestry has been conducted from the biophysical perspective, but socio-economic aspects in relation to perception of farmers should be given more attention.

Combe (1982) classified agroforestry systems into three broad groups, namely agrosilvicultural (mixing trees and crops), silvopastoralism (mixing trees, pastures and animals) and agrosilvopastoralism (mixing trees with crops and animals). According to Rethman et al. (2007) these groups can further be subdivided as either simultaneous (where trees and crops are grown simultaneously), or sequential (where trees and crops are grown separately, temporally, over a number of seasons, as with improved fallows). According to (DAFF, 2017) Agroforestry is a land use system that includes the use of woody perennial and agricultural crops and animals in combination to achieve beneficial ecological and economical interactions for food, fiber and livestock production. It is further emphasized that properly managed Agroforestry system provides multiple benefits and contribute to improved livelihoods and income generation (DAFF, 2017; Maponya *et al.*, 2018; Maponya *et al.*, 2019).

According to Hassan (2013), South Africa is considered a semi – arid country vulnerable to water stress, particularly drought. Limpopo province average annual rainfall is 600 mm and the threshold for rainfall agriculture is averaged at 250 mm annually (ARC, 2017). In terms of forestry, the plantation forests of South Africa use just 3% of the country's total water resources and rainfall needs to be higher than 750 mm per annum to sustain commercial forestry. According to ARC (2017), the relatively narrow escarpment area in the district receives an annual rainfall of 800 to more than 1000 mm. A narrow band of relatively high rainfall (700-800 mm p.a.) runs along the foot of the escarpment. The broad lowveld plain receives 400-

600 mm p.a. The rainfall is very strongly concentrated during the summer months. Summer temperatures are high over the lowveld (Tmax in January 31-34). Winter temperatures are mild over the lowveld (Tmin in July 7-10°C). Regular frost does not occur in the lowveld. The relatively high potential evaporation of 1000-1100 mm during the summer months results in most of the agricultural areas being marginally suited or unsuited to most conventional rainfed arable agriculture enterprises. The Mopani district also falls within the Levuvhu and Letaba WMA. Of the five sub-areas, two (Levuhu/Mutale and Groot Letaba) constitute important irrigation areas with high value crops. Apart from water from the new Nandoni Dam, the surface water resources are over-extended and water for irrigation is being augmented by groundwater. Hence, the objective of the study was to determine the potential constraint of rainwater on the establishment and expansion of agroforestry in Mopani district, Limpopo Province.

MATERIALS AND METHODS

All the research done so far with partners (South African Forestry Company Limited, Department of Forestry & Fisheries, Universities of Kwazulu Natal, Pretoria & Mpumalanga) is focused on achieving or working towards a participatory research approach since the researcher, collaborators, extension officers, farmers and funder were actively involved in all phases. According to Backeberg and Sanewe (2010), the method of participatory action research is most appropriate since peoples especially farmers benefit while the research is ongoing. The participatory action approach was also recommended by various researchers who emphasised that the participatory action approach is a good alternative to the traditional “transfer of technology" or ”top - down approach" to agricultural research and extension. It is against this background that the approach was used to achieve the research objective. The research used quantitative and qualitative methods. A detailed questionnaire written in English was developed as a quantitative data collection method. The qualitative data collection methods included focus group discussions and field observations. A purposive sampling technique was used to select 62 agrosilviculture community growers and were spread on the 20ha SAFCOL forestland (see figure 1) and each grower was allocated a row of 3226m^2 (1ha = 10000m^2; 20ha * 10000 = 200000m^2/62) for production. Socio economic data was analysed quantitatively using the Statistical Package for Social Sciences (IBM SPSS Statistics) windows version. The following approach was used to determine average monthly rainfall (Malherbe and Tackrah, 2003): Decadal (ten day period) 1km x1km surfaces were created from rainfall data (1920 – 1999) downloaded from the AgroMet databank at the Agricultural Research Council- Soil, Climate and Water (ARC-SCW) (South African Weather Service and SCW weather stations) from stations with a recording period of 10 years or more. Regression analysis and spatial modelling were utilized taking into account topographic indices such as altitude, aspect, slope and distance to the sea during the development of the surface.

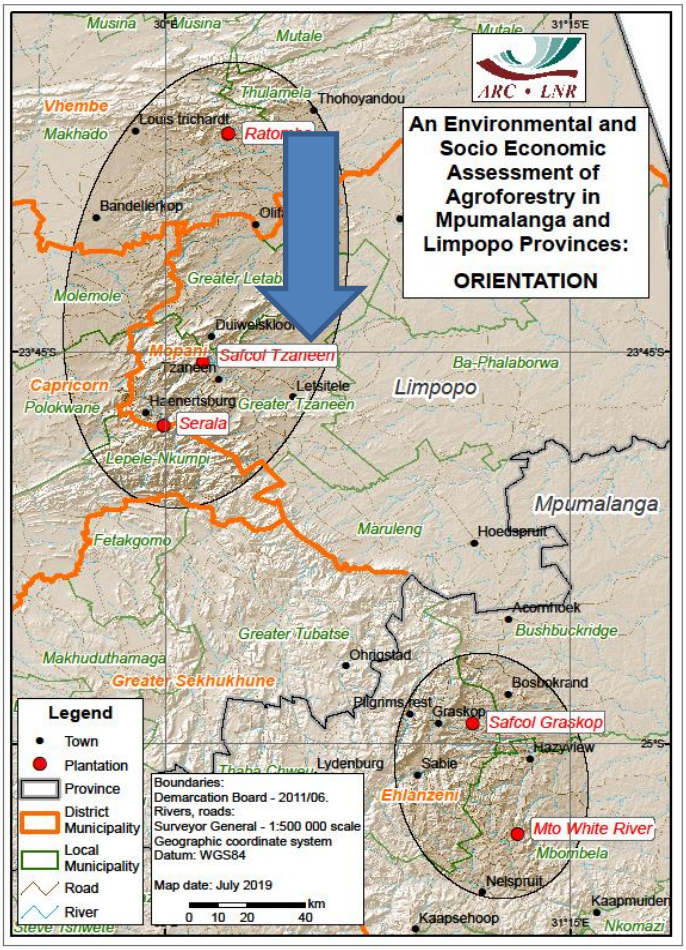

Figure 1. Location of the SAFCOL study area in Tzaneen in Mopani District.

RESULTS AND DISCUSSION

The majority of agrosilviculture community growers interviewed were female. According to Table 1, fifty-eight women were interviewed as compared to four males. In terms of educational attainment (Table 1), 1.6 % of growers had no education, 82% of growers had primary education, 15% of growers had matric while 1.6% of growers had post matric. According to (Maponya *et al.*, 2016) training and education plays an important role in smallholder farmer development and failure to address some of the training needs has led to constrained agricultural growth in some districts in South Africa (Maponya *et al.*, 2014 and Maponya *et al.*, 2015). As indicated in Table 1, all the sixty – two growers were full time engaged in agrosilviculture practice. The growers indicated that they received no training on agroforestry as they mostly relied on their indigenous knowledge system (IKS). Results on land acquisition (Table 1) indicated that the growers were allocated land

by SAFCOL for production.The agrosilviculture community growers also emphasized that they moved away from their villages to the study area in search of its good climate including rainfall. The agrosilviculture community growers indicated that they have experience (See Table 1) and have been practicing agroforestry for decades in the study area as it has improved their livelihood through income generation, job creation and food security. Currently, the eucalyptus trees were integrated with other crops including; maize, sweet potatoes, groundnuts and bambara nuts.The age distribution of the growers indicated that the majority were in the age group of >60 (73%). As indicated in Table 1, youth involvement is very low (6.5%), 36 – 45 (1.5%) while 46 – 59 had 19%. This situation is worrisome and indicates the urgent need to attract young generation into agroforestry as an important priority.

Table 1. Agrosilviculture Community Growers Selected Socio Economic Characteristics

Variables	Growers	% of Growers
Gender		
Female	58	94
Male	4	6
Total	**62**	**100**
Level of Education		
No Education	1	1.6
Primary Education	51	82
Matric	9	15
Post Matric	1	1.6
Diploma/Degree	0	0
Total	**62**	**100**
Employment Status		
Agrosilviculture Community Grower	62	100
Other	0	0
Total	**62**	**100**
Age (Years)		
18 – 35	4	6.5
36 – 45	1	1.5
46 – 59	12	19
>60	45	73
Total	**62**	**100**
Agroforestry Training		
Yes	0	0
No	62	100
Total	**62**	**100**
Agroforestry Experience (Years)		
1 – 5	25	40
6 - 10	7	11

11 - 20	12	19
21>	19	30
Total	**62**	**100**
Land Acquisition		
Own Finance	0	0
LRAD	0	0
Lease	0	0
Inheritance	0	0
SAFCOL Land	**62**	**100**
Total	**62**	**100**

Figure 2 – 8 are self-explanatory. As indicated in figure 2, the September 2019 rainfall results indicated that there was generally good rainfall (25 - 50mm) in the agroforestry sites as compared to the agricultural open field areas. As shown in Figure 3, the October 2019 rainfall situation improved with an increase in rainfall (51 - 100mm). The same trend is observed in all visited and identified agroforestry sites (Ratombo, Serala, MTO White River and SAFCOL Graskop). This situation is also not surprising, as the Department of Forestry & Fisheries (DEFF) has identified those agroforestry sites as pilots.

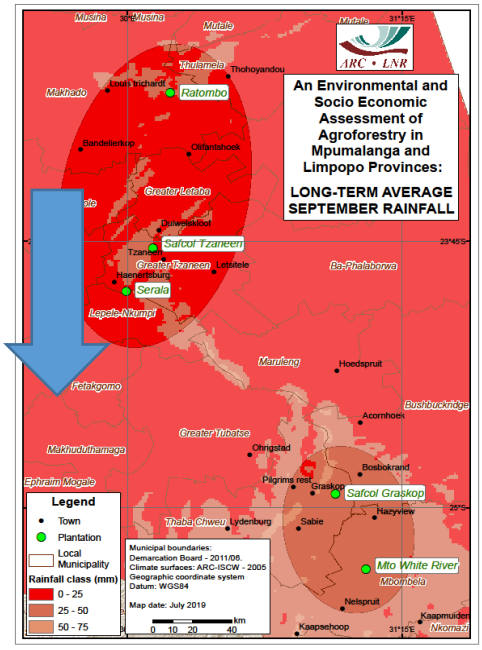

Figure 2. Average September Rainfall

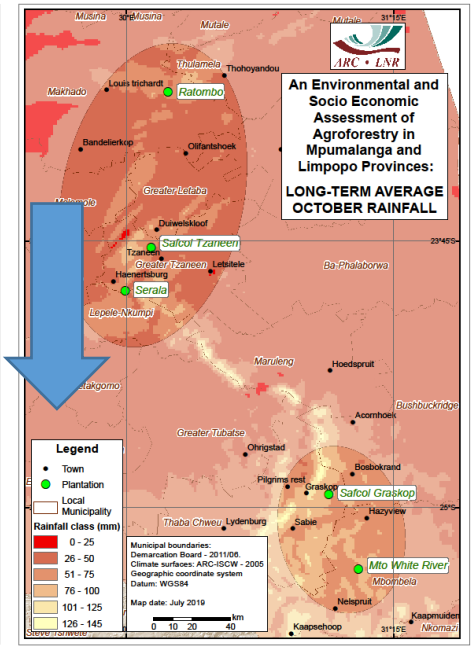

Figure 3. Average October Rainfall

As indicated in Figure 4 and 5 long-term increases in rainfall from November to December are experienced in the study area. During November and December 2019, increasing rainfall was experienced at 100 - 200mm and 175 - 250mm, respectively. The rainfall belt is seen from Ratombo Plantation (Limpopo Province) until the MTO White River (Mpumalanga Province).

This trends offers a good platform for the establishment and expansion of agroforestry as rainwater is not a constraint as compared to the open field agriculture. Hence, there is a movement of communities from their villages to the agroforestry sites in search of good climate.

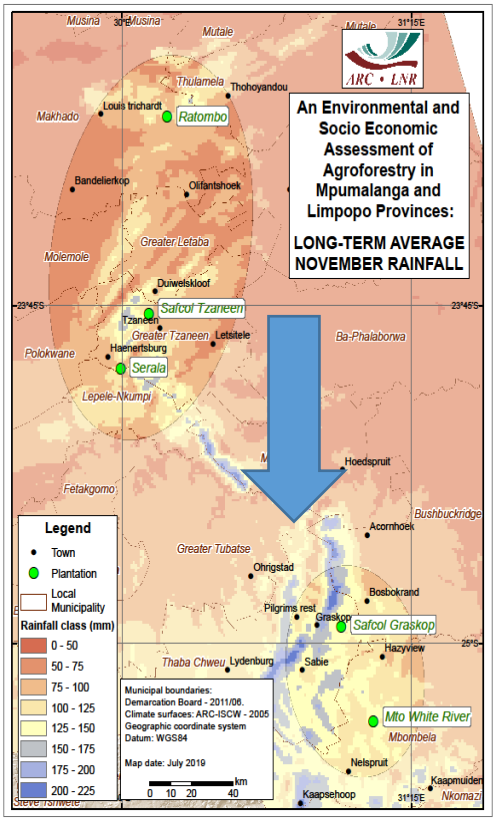

Figure 4. Average November Rainfall

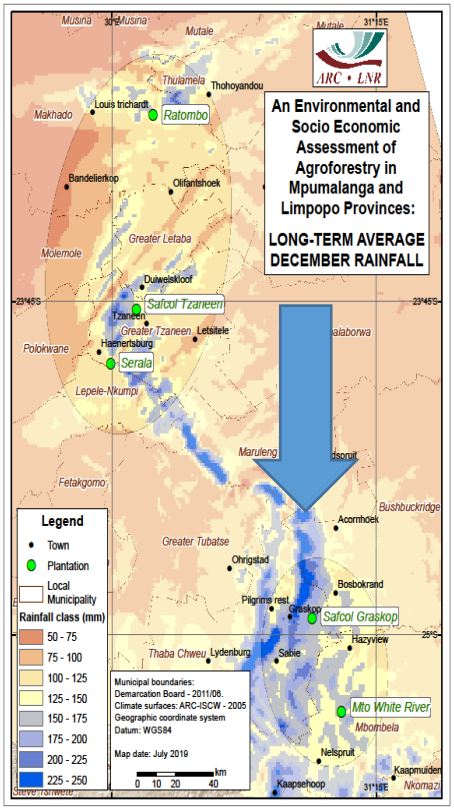

Figure 5. Average December Rainfall

The last three rainfall status (33rd, median & 66th percentiles) indicated the estimates of rainfall in the future years. It estimated annual rainfalls at 601 and +1000mm; +1000mm & +1000mm across 33rd, 50th & 66th percentiles, respectively. This rainfall situation is well above the Limpopo Province annual average rainfall, agriculture and forestry thresholds.

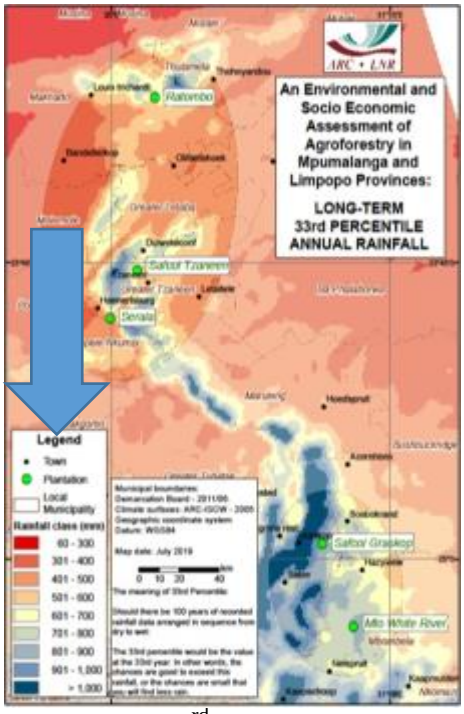

Figure 6. 33rd Annual Rainfall

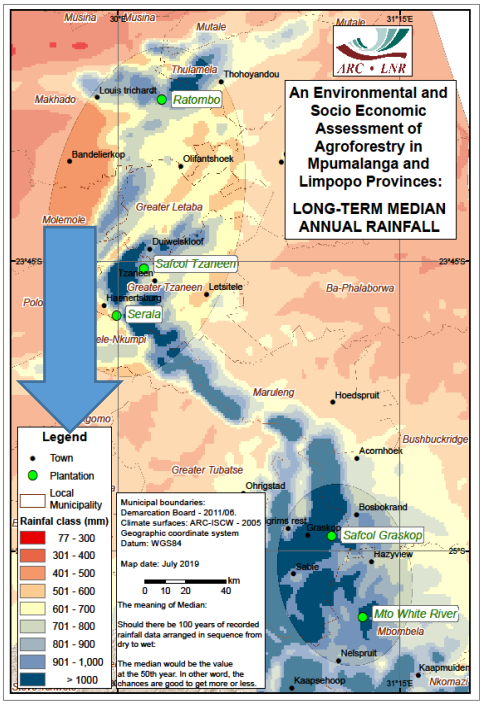

Figure 7. Median Annual Rainfall

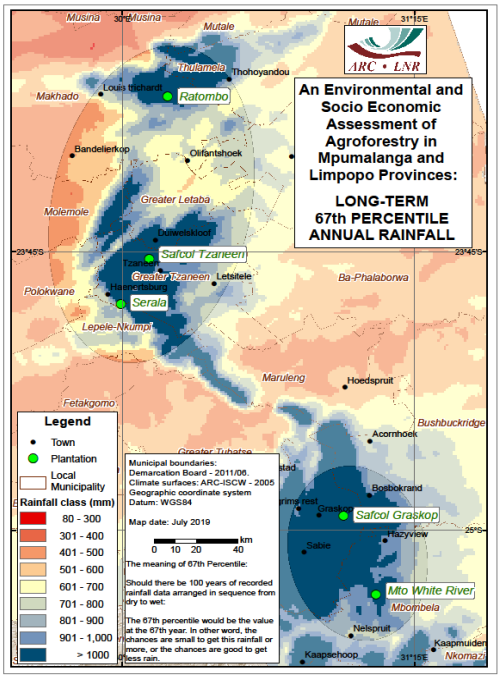

Figure 8. 67th Annual Rainfall

CONCLUSION

It can thus be concluded that rainwater is not a constraint in the study area for the establishment and expansion of agroforestry. Figures 2 – 8 confirms that rainwater is not a constraint for agroforestry establishment and expansion in the SAFCOL Tzaneen agroforestry site. The rainfall belt is also more evident in the agroforestry sites as seen in figures 6 – 8. Currently the eucalyptus trees are integrated with maize, groundnut, bambara nut and sweet potatoes and the communities are relying only on rainfall for irrigation. The study recommends that the establishment and expansion of agroforestry be carried out in the identified suitable areas and in line with the Department of Agriculture, Forestry and Fisheries Agroforestry 2017 Implementation strategy.

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ASSESSMENT OF GENETIC VARIATION AMONG *PISTACIA ATLANTICA* DESF. REGARDING SEXUAL GENOTYPES (MALE, FEMALE AND HERMAPHRODITIC) USING ISSRS. MARKERS

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ABSTRACT

All *Pistacia* species are dioecious, male and female flowers are born on separated trees. Our recent studies identified new hermaphroditic genotypes of *P. atlantica* with different structure of racemes and flowers at the south of Syria. Therefore, the current research aimed to assess genetic variation among 11 genotypes (3 female, 5 hermaphroditic, 3 male) across fifteen ISSRs primers in Sweida Research Center (2018-2019). All of the primers were able to detect the polymorphism, which revealed 214 bands, 205 of them were polymorphic (95.79%). The number of bands for each primer ranged from 6 to 33, with an average 14.27 bands for each Primer. Genetic similarity among all studied genotypes ranged from (0.27) between hermaphroditic genotype (PA52) with female genotype (FA3) as well as between MA3 male genotype and FA2 female genotype, while the highest genetic similarity was 0.77 between two hermaphroditic genotypes (PA37and PA52). Cluster analysis grouped all studied genotypes into three main clusters according to their sexual structure; the first cluster contained all of the hermaphroditic genotypes and the second cluster comprised of all male genotypes, while the third cluster included all female genotypes. The results demonstrated the importance and the efficiency of ISSR technique by revealing the genetic variation among *P. atlantica* genotypes and separating all of them into detached clusters according to their sexual structure. Farther more, some primers were able to detect common bands in each sexual structure which might help to understand the mechanism of sexual inheritance within the studied species.

Key words: *hermaphroditic genotypes, genetic similarity, P. atlantica, ISSR technique*.

INTRODUCTION

Pistacia atlantica Desf. belongs to the genus *Pistacia* and *Anacardiaceae* family as dioeciously trees (karimi *et al*., 2009). The native origin for the genus *Pistacia* is the dry and semi-dry lands in the Iranian Turonian canton in Iran, Turkey and Syria (Padulosi *et al*., 1996). In deed the researches about this species is modicum, and the information of environmental and morphological trends was not clearly studied

among the populations (Belhadj *et al*., 2007). *P. atlantica* Desf. species is considered as one of the most important genetic rootstocks for commercial cultivars of *P.vera* and provide a great gene-pool for genetic improvement and breeding programs, since this species tolerate the vital and non-vitals conditions due to their deep root system which activate the uptake process of mineral elements. Special individuals as hermaphroditic patterns of different racemes and flowers structure was found naturally in Sweida governorate (Alhajjar *et al*., 2011). Kafkas (2002) mentioned that all species of the genus *Pistacia* are dioecious and this phenomenon has a negative effect on both of yield and nut's quality, and hermaphroditic genotypes were found in Yunt Mountains in Manisia governorate. Isfendiyaroglu (2007) referred to hermaphroditic flowers in some *P. atlantica* genotypes in Izmir region. Furthermore, Gercheva *et al*. (2008) reported that the monoecious phenomenon in *Pistacia atlantica* supposed to generate in the second generation, hence studying the mono and bi-sexual individuals and their hybrids using molecular markers contribute to clarification of inheritance mechanism of this peculiarity in the genus. The importance of these genetic hermaphroditic genotypes is an economic indicator through its benefits in breeding programs with *Pistacia vera* species in the aim to transfer this sexual behavior into the traditional pistachio cultivars. In the same domain, Abdelkader *et al*. (2009) mentioned conformable hermaphroditic genotypes of *Pistacia atlantica* in Morocco. Breeding programs between hermaphroditic *Pistacia atlantica* genotypes "as pollen donors" and two pistachio cultivars (Ohadi and Siirt) was carried out in Turkey (Kafkas *et al*., 2005). Turkeli and Kafkas (2013) assessed the first genetic linkage map depending on the hybrids between Siirt cultivar and the hermaphroditic *P.atlantica* genotype PA18. Biotechnology is an important technique in breeding programs once ISSRs. (Inter simple sequence repeat) is well-thought-out as one of the most important molecular markers in genetic studies, and it depends on semi-arbitrary sequences for specific microsatellite loci, it is also an easy and rapid method that doesn't need preceding knowledge of the studied genome with high repetitive frequency and high percentage of genetic variance (Kebour *et al*., 2012). The current study aimed to clarify the genetic relationships among hermaphroditic, female, and male *Pistacia atlantica* genotypes using ISSRs markers which contribute to understand the genetic variance that pretend to be associated to the sexual inheritance mechanism in the genus *Pistacia* to highpoint the breeding and hybridization programs.

MATERIALS AND METHODS

This investigation was carried out at the General Commission for Scientific Agricultural Research, Sweida Research Center - molecular biology laboratory during 2018-2019.

Eleven sexual *Pistacia atlantica* genotypes were investigated; 5 hermaphroditic genotypes (PA12, PA13, PA35, PA37, PA52), 3 female genotypes (FA1, FA2, FA3), and 3 male genotypes (MA1, MA2, MA3).

Samples of young leaves of all sexual structure genotypes of *P. atlantica* were collected and DNA extraction was done by using CTAB protocol depending on Porebski *et al*. (1997). DNA quantity and quality were estimated using spectrophotometer (Eppendorf, Germany) by measuring the absorbencies at A260 and A280 nm.

Fifteen ISSRs primers were used and the amplified reactions were done in a 25μL volume containing 10X PCR buffer; 100 mM Tris-HCl (pH 8.4), 500 mM KCl. 2 mM of each of the dNTPs, 10Pmol primer, one unit of Taq DNA Polymerase enzyme (*Go taq*) and 50 ng of genomic template DNA. The PCR products were detected by electrophoresis on 1% agarose gel and then it was visualized after exposing to UV rays using gel documentation (VILBER LOORMOT Germany)

The amplified bands were scored either as present (1) or absent (0). Genetic similarity between any two genotypes was calculated from the bands across the 15 ISSR markers using Jaccards' similarity coefficient (Jaccard, 1908). Polymorphism percentage was estimated according to the equation: the number of polymorphic bands / the total number of amplified bands × 100. A dendrogram was constructed using UPGMA method. The software programs used through this study were Microsoft EXCEL and Past program.

RESULTS AND DISCUSSION

Levels of polymorphism and discriminating of the assay

The number of amplified bands ranged between 6 bands using primer ISS7 to 33 bands using ISS5 primer with an average 14.27 bands for each applied primer in all the different sexual structures of *Pistacia atlantica.* The total number of amplified bands was 214 that 205 bands of them were polymorphic figuring polymorphism percentage of 95.79%. Figures (1) illustrate the amplified bands using primers K24. The number of generated bands in the current study was widely higher in comparison to literature studies that Noroozi *et al*. (2009) obtained only 28 bands of which 13 bands were polymorphic with an average of 9.3 bands for each primer. Fares *et al*. (2009) mentioned that ISSRs markers detected a higher percentage of polymorphism (26 bands). Kebour *et al*. (2012) indicated to 111 bands throughout 6 ISSR primers applied on *P. vera* cultivars of which 60 were polymorphic bands (54.04%). The polymorphism percentage for each primer ranged between 72.73% using K25 primer to 100% in ISSRs primers; K24B, K24A, K26, A6, A5, ISS6, ISS5, ISS3, and ISS2. Band's size ranged between 200-1238bp. The primer ISS6 detected the highest bands number (33 bands) of the size ranged between 440-1203 bp, whereat all of them were polymorphic and the number of unique bands among them was 21 unique bands. In addition, the primer K11 amplified 27 bands where only one band which was monomorphic with a polymorphism percentage 96.30% and the number of unique bands were 11 bands (table- 1). Turhan-Serttas and Ozan (2018) mentioned low bands size in comparison with our current results that ISSR primers detected 81 bands in a range of 161-188 bp only and polymorphism percentage 96.3%. The band size 1079 bp was shared between the hermaphroditic genotype PA35 and the two male genotypes (PM1, PM2) in the primer K11, while

the band size 628 bp was shared just in all female genotypes using the same primer. Likewise, the primer ISS5 amplified the band (565 bp) among all male *P. atlantica* genotypes, whereas this band was absent in all other genotypes (female and bisexual genotypes). Accordingly, these primers may primarily use for detecting responsible sexual genes. This result is corresponding with Ehsanpour *et al*. (2008) while referring to the possibility of sexual determination in pistachio male and female cultivars using ISSR primers whereat they use 9 primers and 2 of them (AC)CG and (AC)8TA were capable to detect each sexual mechanism behavior for male and female patterns.

Table 1. The total number of amplified bands, polymorphism percentage, number of unique bands and band's size (bp)

Primer	**No. of amplified bands**	**No. of polymorphic bands**	**Polymorphism %**	**Band size bp**
ISS2	8	8	100	1003-418
ISS3	9	9	100	1176-426
ISS5	33	33	100	1203-440
ISS6	15	15	100	1055-365
K25	11	8	72.73	855-246
A4	13	12	92.31	723-274
A5	18	18	100	1238-367
A6	12	12	100	715-394
K11	27	26	96.30	1079-200
ISS7	6	5	83.33	699-419
K26	13	13	100	766-252
K24A	8	8	100	615-348
K24B	16	16	100	850-241
UBC840	15	14	93.33	993-343
A2	10	8	80	944-388
Total	**214**	**205**	**95.79**	
Average	**14.27**	**13.67**		

Figure-1: Amplified bands across using K11 ISSR primer.
Genetic similarity. M: DNA molecular weight 100bp ladder

The results showed that the lowest percentage of genetic similarity was 0.27 between the hermaphroditic genotype PA52 and the female genotype FA3, also between the male genotype MA3 with the female genotype FA2. The highest percentage of genetic similarity was 0.77 between the two hermaphroditic genotypes PA52 and PA37. The average of genetic similarity between female and male *P.atlantica* genotypes was 0.326, whereas it was 0.395 between female and hermaphroditic genotypes, and 0.412 between male and hermaphroditic genotypes, which means that the genetic similarity between the hermaphroditic genotypes and both of male and female genotypes was somehow equivalent. Genetic similarity among each of sexual structure was as following: 0.588 among hermaphroditic genotypes, 0.655 among female genotypes and 0.568 among male genotypes (table- 2). In comparison with previous studies Mahmoodnia and Malekzadeh (2017) indicated to genetic similarity percentage ranged between 25- 78% across 12 ISSR primers on 56 male and female pistachio genotypes. Turhan-Serttas and Ozcan (2018) indicated to a high genetic similarity 0.9333 between two *Pistacia lentiscus* genotypes.

Table 2. Genetic similarity using 15 ISSR primers among all sexual genotypes of *Pistacia atlantica*

	FA 1	**FA 2**	**FA 3**	**PA12**	**PA13**	**PA35**	**PA37**	**PA52**	**MA1**	**MA2**	**MA3**
FA1	1.00										
FA2	0.71	1.00									
FA3	0.59	0.66	1.00								
PA12	0.49	0.51	0.54	1.00							
PA13	0.47	0.39	0.46	0.66	1.00						
PA35	0.37	0.33	0.46	0.53	0.64	1.00					
PA37	0.35	0.34	0.32	0.54	0.54	0.49	1.00				
PA52	0.32	0.31	**0.27**	0.47	0.52	0.44	**0.77**	1.00			
MA1	0.39	0.42	0.39	0.47	0.46	0.51	0.44	0.41	1.00		
MA2	0.29	0.29	0.32	0.42	0.49	0.45	0.41	0.43	0.65	1.00	
MA3	0.28	**0.27**	0.28	0.31	0.35	0.33	0.34	0.36	0.52	0.55	1.00

Cluster analysis

The cluster analysis using UPGMA method divided all genotypes into three main clusters according to their sexual structure; the first cluster comprised all hermaphroditic genotypes which were distributed into three sub-clusters, the first sub-clusters contained two bisexual genotypes (PA12, PA13) and the second one only contained the bisexual genotype PA35, while the other two hermaphroditic genotypes PA37, PA52 were localized in the third sub-cluster. The second cluster comprised all male genotypes that divided into two sub-clusters, the first one comprised both of MA1 and MA2, while the third male genotype was lonely situated in the second sub-cluster. The third main cluster contained all female genotypes and it was also divided into two sub-clusters, the first one contained only the female genotype FA3, whereas the second sub-cluster comprised both of the other female genotypes (FA1 and FA2) as it is shown in figure (2).

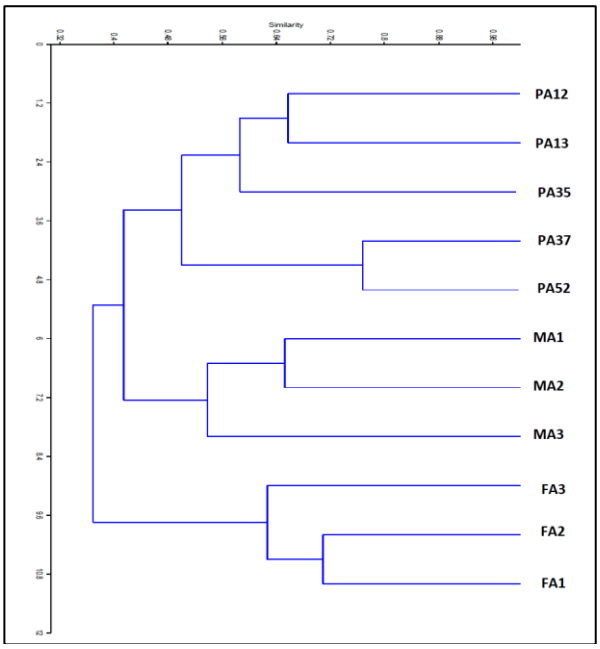

Figure- 2: cluster analysis according to Jaccard coefficient

Genotyping identification by unique DNA markers

Unique DNA markers obtained by ISSR primers were used in the current study to characterize the different sexual *P. atlantica* genotypes. All applied primers were able to detect positive unique bands except the primer A2. The overall number of all unique bands in all genotypes was 73. The hermaphroditic genotype PA37 as well as the male genotype MA2 presented the highest number of unique bands upward to 11 bands, followed by the male genotype MA3 (10 unique bands), while the lowest number of unique bands was 3 in the male genotype MA1.

CONCLUSION

In conclusion all the detective primers were of high efficiency of illuminating the genetic polymorphism and the unique bands. The most substantial point that the cluster analysis detached all investigated genotypes according to their sexual structure as male, female and hermaphroditic genotypes. Consequently, this index considers as a preliminary exponent assist in determining sexual responsible genes which might contemplate as an introductory sight in studying the sexual genetic mechanism in the genus *Pistacia*. The current investigation persisted in the importance of farther molecular studies using higher number of primers that aids to profound comprehension of genetic variance which is might connected to sexual inheritance that facilitates breeding programs and opened new vision in genetic studies within the genus *Pistacia*.

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METHODOLOGICAL PROPOSALS FOR ADDRESSING AGROECOLOGICAL DESIGN IN PERIURBAN AREAS: A CASE STUDY IN THE EDGES OF MILAN (ITALY)

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ABSTRACT

This study aims to develop an ecological-based design model, applying the theoretical basis of landscape ecology and phytosociology on a pilot area located in the Milan South-Eastern rural edges. The goal was to integrate an all-inclusive approach for agroecological regeneration. Three main guidelines were identified: 1. the rehabilitation of landscape texture; 2. internal diversification; 3. environmental consistency. The study led to a global evaluation of the ecological functionality of the different environmental compartments, analysing their weaknesses and resiliences. Consequently, design criterions were defined, regarding the landscape level (ecotopes diversification) and the single ecotope level (vegetational standards), reconfiguring the current uses and functions and enhancing the biological and structural diversity within the agroecosystem. Finally, an evaluation of the benefits on ecological functionality was carried out, as well as a qualitative assessment of the ecosystem services that can be delivered. This approach enabled to make direct comparisons between actual and project scenarios, supporting the readability of the rebalancing effects attainable on the environmental, social and economic scale.

Keywords: *Landscape ecology, Agroecological design, Ecosystem services, Peri-urban, Italy.*

INTRODUCTION

There is growing sensibility towards peri-urban areas role in strategic planning processes (European Commission, 2019). Current social, economic and environmental features do configure challenging scenarios regarding the capability of cities to absorb and redirect actual and potential impacts and disequilibrium of urban systems towards a resilient and durable reconfiguration of its processes (European Commission, 2013). European metropolitan planning latest trends are moving towards a de-centralized approach, aiming to recognise the interdependencies and interconnection between urban and rural systems as essential topics for attaining a sustainable integrated metropolitan development (SUL & NBS Partnership, 2018; Climate Adaptation Partnership, 2018; Rossi, 2005).

In line with Global, European and National guidelines (United Nations, 2019; IPCC, 2019; European Parliament & Council, 2013; EEA, 2012), Milan Metropolitan City (Lombardy, North of Italy) has adopted different strategic planning tools directing towards an integrated approach to urban development. The most relevant are the *Milan Food Policy Pact* (Montpellier Declaration, 2019), the *AQST "Milan Rural Metropolis"* (a Framework Agreement for Territorial Development based on the strengthening of the urban-rural matrix) (Regione Lombardia, 2015) and the recently adopted *Milan PGT* (Comune di Milano, 2018), built on the main axes of connection, inclusion, resilience, decentralisation, regeneration.

In this perspective, regenerating rural peri-urban areas implies a multi-compartments integration of social, economic and environmental issues, embracing their direct and indirect mutual impacts and benefits (Zasada, 2011). On the ecological side, strong interactions occur between the urbanised matrix and the neighbouring rural and natural areas, thus strongly influencing the ecological dynamics of biotic and abiotic systems, concerning their resources, energetic and biotic flows (Donadieu, 1998; McDonnell M.J. *et al*., 2008). Consequently, environmental stability, complexity, inner diversification and hence, resilience of peri-urban rural systems are highly influenced by the way the urban system interacts and relate itself with rural outskirts. When facing ecological re-design issues in such contexts, it is primarily important to take into account this network of mutual interactions, allowing a correct interpretation of the ecological functioning of environmental and landscape features and thus, a coherent and effective design setup. In this regard, landscape ecology and phytosociology sciences can give a consistent contribution.

Within this framework, this study was focused on developing an ecological design model for peri-urban rural areas, outlining an evaluation reference framework for the improvement of their environmental resilience.

This model was applied on a pilot area located in the Milan South-Eastern rural edges, namely an area of 73 ha of agricultural land located in the first strip of the Vettabbia Valley (inside the Rural Park South Milan), next to the last city buildings, an area marked by a deep historical background (Figure 1). The peculiar location of the pilot area regarding urban fabric, its historical role towards the city and the existence of different previous agro-ecological design visions developed during the last years make this area a fitting candidate for studying peri-urban ecological dynamics. Specifically, the OpenAgri project linked to the European program of Urban Innovative actions (www.uia-initiative.eu/en) and the Milano PortaVerde 2030 project (Comune di Milano, 2019), which directly carries on the OpenAgri vision of creating an Agroforestry Park for agroecological experimenting, were the starting landmarks of this study.

Figure 1. The study area location (Milan, North of Italy) (*Source: Author's elaboration).

Materials and methods

In order to achieve the above-mentioned goals, the study was developed through 4 main steps (Figure 2). In all steps, the main focus was addressed on the natural system, considered as an environmental unit synergistically interacting with anthropic and agricultural matrices.

Figure 2. Methodological setting: the four main steps of the study.

Firstly, a preliminary analysis was carried out, aimed at characterising the current state of the area, regarding its environmental, landscape, social and historical traits. GIS diachronic analysis at large and small scale allowed an overall characterization of the main ecologically significant features (www.geoportale.regione.lombardia.it). Global BioClimatics tools (www.global bioclimatics.org) allowed a bioclimatic classification of the area (Rivas-Martinez *et al*., 2011). Onsite surveys were focused on collecting floristic, vegetational, faunal and observational data. A floristic list was edited, allowing a chorological and ecological interpretation (Pignatti, 1982; Pignatti *et al*., 2017-19; Pignatti *et al*., 2005; Domina *et al*., 2018; Guarino *et al*., 2012; Brusa and Rovelli, 2010). Physiognomic and structural vegetation patterns were studied, referring to phytosociological guidelines of Zurich-Montpellier school (www.prodromo-vegetazione-italia.org). A monitoring program for avifauna and entomofauna (Odonata and Lepidoptera) was set up during six months, allowing an interpretation of the ecological characters of existent faunal biocenosis (Cunningham and Johnson, 2006; Pollard and Yates, 1993; Ketelaar and Plate,

2001). Landscape ecological patterns were studied, based on the landscape ecology approach (Dramstad *et al*., 1996; Baudry and Burel, 1998; Forman and Godron, 1986), namely through a functional and morphological analysis, examining its spatial layout and its connectivity, fragmentation and ecotone properties.
The second evaluation phase was developed through a multi-level and multi-compartment assessment of the preliminary analysis results, outlining the overall weaknesses and potentialities of the area. This evaluation was the starting point for the identification of design criterions, adjusting them to local ecological needs.
A final assessment of the project scenario influences on the overall ecological functionality was carried out merging diversified theoretical approaches linked to ecological design and Ecosystem Services assessment (MEA, 2005; Grant, 2012; Malcevschi and Lazzarini, 2013).

Theoretical framework for agroecosystem distinctive features

On the theoretic side, the strengthening of environmental stability was identified as the main goal for the ecological reconfiguring, considering it as the expression of a dynamic equilibrium state of the system, depending on the inner mutual support of auto-regulation processes. Within agroecosystems, the natural trend towards diversification is constantly interrupted, keeping the system at low level of complexity (pioneer behaviour), where high productivity is supported by constant external inputs intended to control ecosystem regulation processes through outside drivers (Gliessman, 2007). Thus, supporting agroecosystem stability demands to re-balance the disturbances linked to the lack of self-sufficiency of the system (Gliessman, 2007). In this regard, the recovery of agroecosystem inner diversification was identified as the key action tool, in the perspective of a global balancing of anthropic and natural functions (Fabbri, 1997; Battisti, 2004; Gliessman, 2007; Malcevschi *et al*., 1996; Franco, 2000; Burel, 1992; Baudry and Burel, 1998; Burel, 1996; Forman, 1995; Forman and Godron, 1986). This meant to focus the strategic re-design of the area taking into account functional and dynamic features of its natural and semi-natural elements, considered as fully integrated in the rural matrix. Globally, this issue was developed, in all its steps, addressing at three main ecological organisation levels (space-related and time-related): 1. landscape level; 2. ecotope level; 3. single species level.

RESULTS AND DISCUSSION

1.Preliminary analysis results

Floristic characterization showed a significant presence of allochthonous species (22%; 16% invasive alien species). Geophytes and therophytes percentages were interpreted as linked to recurrent disturbance conditions. Ellenberg's Indicator values (Pignatti *et al*., 2005; Domina *et al.*, 2018; Guarino *et al*., 2012) showed a slight preference for higher insolation, temperature and soil acidity conditions among allochthonous species.
Phytocenosis characters were linked to open habitat properties, with a low level of diversification, due to the dominance of nitrophilous, ruderal and invasive exotic

species. They were attributed to the vegetation stages of the secondary dynamic, linked to synanthropic substitution series and initial dynamisms (Verde *et al.*, 2010).

Animal communities were found to be dominated by synanthropic species, linked to low habitat quality traits, according to literature (Baietto and Padoa-Schioppa, 2008; Battisti, 2004).

Concerning the landscape features, it was identified a low level of connectivity between the spontaneous phytocenosis within the area, a low-mitigated impact of barriers and compromised ecotone functionalities.

2.Ecological functionality evaluation

Preliminary analysis results allowed a global interpreting and evaluation of the ecological functionality of the different environmental compartments and their mutual relations. The landscape system, the natural system (hedgerows and tree lines, woods, riparian and boundary phytocenosis), the hydric and irrigation system and the productive agroforestry system were assessed. Their specific weaknesses and resiliency were evaluated by drawing up synoptic schemas highlighting their current impacts and potential contributions to the overall environmental stability of the area (an example is shown for the landscape level) (Figure 3).

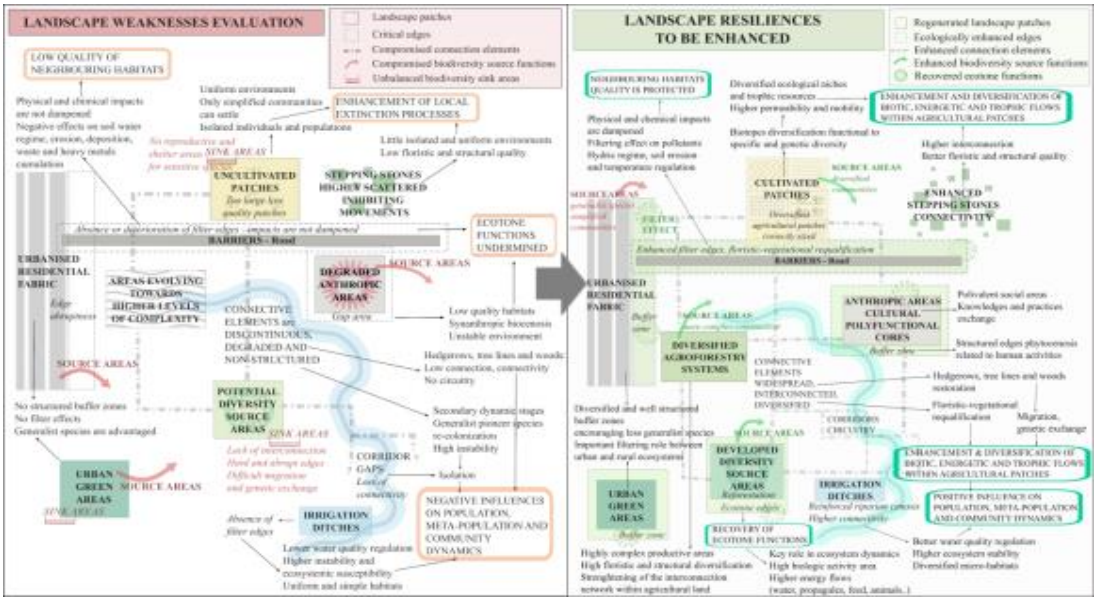

Figure 3. Synoptic schemas for the evaluation of landscape ecological weaknesses and potentialities (*Source: Author's elaboration).

3a. Identifying a design approach

Based on this global assessment, the methodological approach for intervention was outlined. Three main guidelines were identified: 1. the rehabilitation of landscape texture; 2. internal diversification; 3. environmental consistency.

At the landscape level, priority was given to the rehabilitation of landscape texture and its spatial and dynamic ecological features (connection, connectivity, circuitry, ecotone functions), which were taken into account through a qualitative estimate (Figure 4).

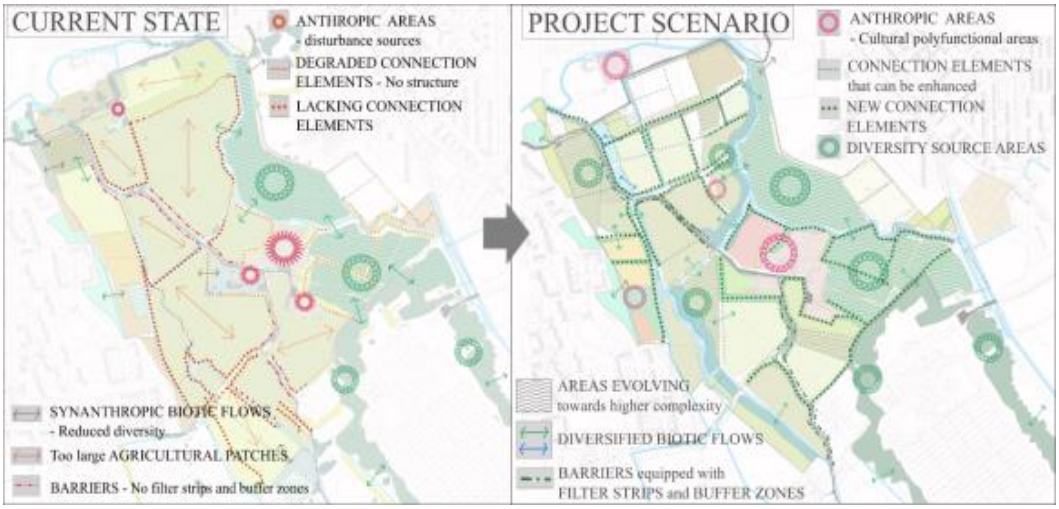

Figure 4. Evaluation of the potential effects of landscape rehabilitation on the ecological functionality within the area (*Source: Author's elaboration).

At the ecotope level, it was identified a functional and dynamic approach for interpreting current biocenosis behaviour and its possible adjustment through design interventions. The focus was addressed on the ecological niche concept, namely by studying the distinctive traits of the different habitats and their related ecological and dynamic functions. Current biocenosis were related to recurrent disturbance conditions, first successional stages and to open spaces properties. Thus, their dynamic role was identified in soil covering and first soil preparing conditions. The environmental conditions predispose to the settlement of R-strategy species (Gliessman, 2007; Odum and Barrett, 2005), thus enhancing competitive, predatory and parasitic ecological behaviours. These conditions lead to the simplification of current biocenosis, in terms of ecosystem structure and inner biodiversity.

Hence, potential interventions were focused on modifying the populations and community roles within the ecosystem (physical space, trophic role, interspecific relations) through the ecotope restructuring, thus adjusting the current trends towards a higher equilibrium between competitive, predatory, parasitic, mutualistic and commensal roles. The main guideline was identified in the encouragement of intermediate successional stages within phytocenosis, (insertion of medium-long cycles species with slower dynamic trends, the increase of structural diversification, the stabilization of micro-climatic site conditions, organic matter storage, soil structuring, nutrients and trophic resources availability). Thus, newly

inserted phytocenosis were conceived as drivers for the system evolution towards a higher environmental overall stability, able to support more complex communities, where R-strategy species are balanced by K-strategy species.

At the single species level, selection criteria were identified in: 1. consistent native species [in reference to local climacic vegetation series (Verde *et al*., 2010; Brusa and Rovelli, 2010) and to site environmental conditions]; 2. synecological and syndinamic behaviour (for identifying species able to progressively substitute the exotic ones); 3. their insertion modalities and necessary predisposing conditions (in reference to the specific site needs for species settlement and stabilization over the time). In this perspective, shrubs were considered as key design elements, for their soil-building capabilities and their site condition stabilization role.

3b. Design development

The above-mentioned methodological assessment brought to a global reconfiguring of uses and functions within the area (Figure 5).

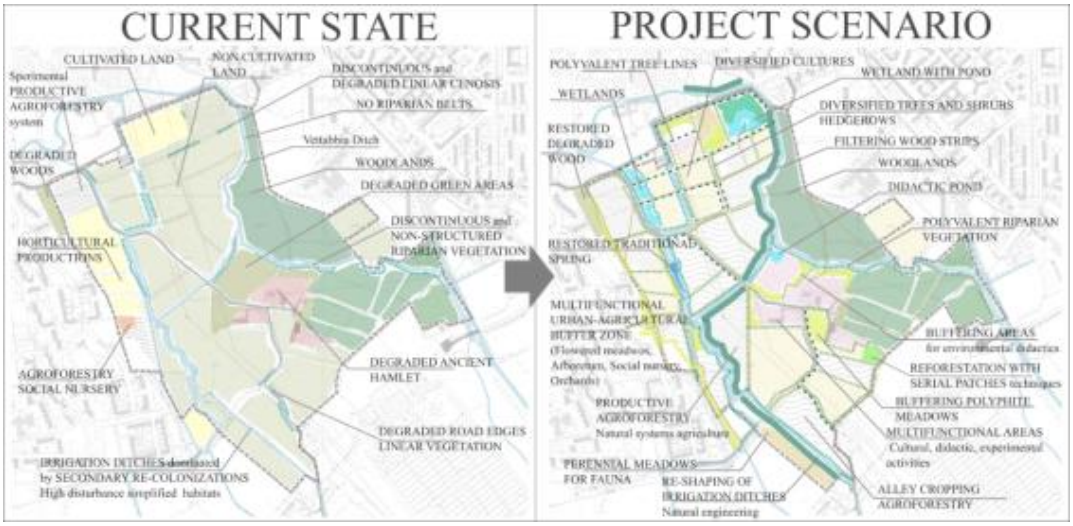

Figure 5. The project's transformation scenario (*Source: Author's elaboration).

Interventions were studied within six different actions: 1. linear cenosis equipment (hedgerows and tree-lined networks); 2. requalification of the riparian system; 3. wood patches re-conversion to native cenosis; 4. edges strips requalification; 5. hydric and irrigation systems ecological integration; 6. productive agroforestry systems implementation.

Ecotope diversification resulted in the insertion of a variety of habitats, environmental structures and cenosis, with different primary functions (preparatory, predisposing, protective, regulating, connective, naturalistic, feed-supplying, and also recreational and didactic). For example, the hedgerows system was reconfigured aiming at maximizing its polyfunctionality, recovering its interconnection, its cenosis stratification, texture and floristic diversification. Their sought functions were: soil protection, microclimatic regulation, ecological corridor, biodiversity support, trophic and food supply, pollination services delivering.

An important design theme were edges and boundaries in-between natural and anthropic patches and barriers. Their morphologic and spatial configuring was aimed at enhancing buffering effects towards anthropic impacts. Buffer zones along urban edges play an important role in filtering and creating relations, thus supporting a positive integration and permeability between the two systems, mitigating the impacts of urban dynamics on biodiversity and environmental quality. The higher environmental quality was sought through an appropriate species selection (native species belonging to climacic successional series).

4.Project scenario evaluation

An overall evaluation of the benefits on ecological functionality expected from the landscape project reconfiguring was carried out. The aim was to put in evidence its positive influence on the system capability to enhance and preserve environmental stability. These results are summarized in the Figure 6, which underlines the overall regulating benefits coming from the multi-level, multi-compartment and multi-strategy approach implemented in this study.

Finally, a qualitative assessment of the ecosystem services (ES) that can be generated was implemented (Figure 6), linking each intervention category to the different types of ES (Malcevschi and Lazzarini, 2013; MEA, 2005), evaluating their importance for delivering the ES. This enabled to make direct comparisons between actual and project scenarios, thus supporting the readability of the rebalancing effects and added value attainable on the environmental scale, as well as on its social and economic implications.

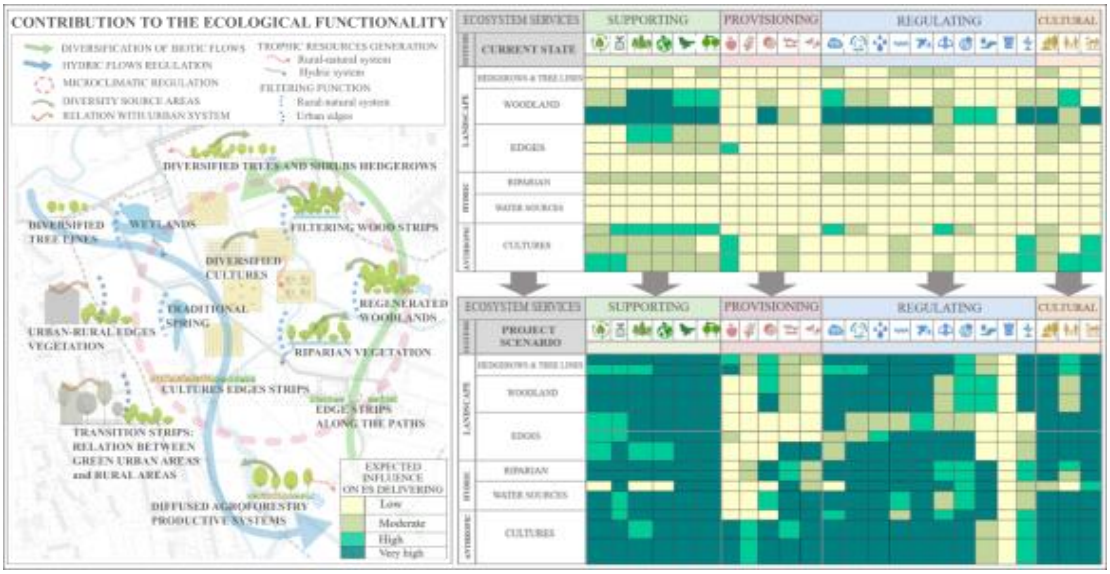

Figure 6. Evaluation of the benefits attainable on ecological functionality and on the delivering of Ecosystem Services (*Source: Author's elaboration).

CONCLUSION

Through this study, it was possible to outline an all-inclusive approach for regenerating rural peri-urban areas, embracing their diversified ecological issues and putting in evidence key strategies for the enhancement of environmental stability parameters.

Agroecological design role in mitigating environmental and social outskirt weaknesses and in generating new resources and services was highlighted.

Therefore, this methodological framework is suitable for the implementation on peri-urban contexts similar to the provided case study.

Further integrations of these methodological proposals would enhance their environmental effectiveness, namely by developing monitoring strategies over the time and by including a quantitative assessment of landscape features, inner resources changes, and ES delivering.

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CROPS WATER CONSUMPTION AND VERTICAL SOIL MOISTURE EXCHANGE

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ABSTRACT

A various number of factors, which, in turn, also vary greatly, determines the process of water consumption. These are meteorological indicators, yield, crop properties and soil conditions. The values of the water consumption of irrigated crops (in the operational regime of irrigation in the calculation of the water balance) are recommended to be determined counting on: the indicators of heat supply of the territories, that is, the radiation balance; air humidity deficit and bioclimatic factors of water consumption, taking into account the type and phase of plants development, the physical condition and the soil moistening. The empirical method for determining the vertical moisture exchange takes into account the biological characteristics of crops, the conditions for the heat and moisture availability of the calculation periods, the power and humidity of the soil layer under study, the water-physical properties of the ground, and the depth of the groundwater. It gives reliable results and can be used in calculations of the water regime in designing and exploitation of the reclamation systems. The groundwater affects the formation of the soil water regime in the aeration zone. At shallow occurrence, they increase the humidity in the root layer, which makes it possible to reduce the irrigation rates and the number of irrigation events. This article considers the problem of reducing errors and improving existing methods of calculating water consumption by crops and vertical soil moisture exchange. The methods of (Shebeko *et al*., 1980), Rogotskiy (1981) and Pylenok (1985) were taken as the basis of the research. According to them and empirical formulas developed by Mazaiski (2002), the calculations of vertical moisture exchange were made. The empirical method for determining the vertical moisture exchange takes into account the biological characteristics of crops, the conditions for the heat and moisture availability of the calculation periods, the power and humidity of the soil layer under study, the water-physical properties of the ground, and the depth of the groundwater. It gives reliable results and can be used in calculations of the water regime in designing and exploitation the reclamation systems.

Keywords: *soil moisture, water consumption, infiltration, radiation balance*.

INTRODUCTION

Soil moisture plays a crucial role in the hydrological cycle and climate system. The reliable estimation of soil moisture in space and time is important to monitor and even predict hydrological and meteorological disasters (Wang *et al*., 2018). Soil moisture dynamics have important impacts on theclimate–soil–vegetation system. A wide number of hy-drometeorological processes can be ascribed to water andenergy exchanges between soil and the near-surfaceatmosphere (Daly and Porporato, 2005). Soil moisture refers to the water present in the uppermost part of a field soil and is a state variable controlling a wide array of ecological, hydrological, geotechnical, and meteorological processes (Romano, 2014). The most agricultural climate change impact studies have focused on the impact on crop productivity (Mourice, 2017; Hatfield, 2011). However, changes in temperature, radiation and precipitation do not only affect productivity it also has an impact on plant water use. With agriculture being the number one water user across the globe changes in agricultural water use will have large impacts on water availability (Supit et al., 2010). Soil hydrological processes play an important role in land-atmosphere system. In most climate models, these processes are described by soil moisture variations in the first 2 m of soil resulting from precipitation, evaporation, and transpiration. Groundwater effects on soil moisture variations and surface evaporation are either neglected or not explicitly treated (Chen and Qi Hu, 2004). A huge number of factors, which, in turn, also vary greatly, determines the process of water consumption. These are meteorological indicators, yield, crop properties and soil conditions (Shebeko *et al.* 1980, Kapuściński, 2000). The close relationship of water consumption is noted with the radiation balance, and it has a close relationship with other meteorological factors (Bryś, 2013). The made experimental researches, statistical and correlation analyzes show that in the calculations of water consumption, the radiation balance or the deficit of air humidity can be used as meteorological factors (Bryś *et al*. 2018). The thermal energy presence for evaporation are indicators of moisture availability, have close relations with water consumption and heat costs for evaporation (Bac and Kuchar 2001).

MATERIAL AND METHODS

The study was conducted in the Ryazan district, Russia. According to natural data and the empirical formulas, the calculations of vertical moisture exchange were made. Object situated in Ryazan district, Russia, in Oka river basin; soil - sandy loam; surface slope 0,001-0,005; groundwater from 1-2 m to 8-10 m deep. Lysimeters were installed and groundwater levels were maintained at a depth of 0.7; 1.1; 1.5; 1.9 and more than 2.5 m with irrigation system help; drainage system 0.7-2.0 m depth. Biological properties of crops (lupine, potatoes and oats) were used: development phases; height; leaf surface area; biomass weight.

The soil moisture layer was taken differentiated according to the phases of crops development, taking into account an increase in the vegetation mass and 90% accumulation of the root system in it: 20-30 cm at the beginning and 30-50 cm at

the end of the growing season. Watering was carried out at a rate of 10-25 mm, increasing soil moisture to field capacity.

The study was carried on by using the daily average moisture deficit, average air temperature and daily precipitation, soil temperature, wind speed, radiation data of the Ryazan (Russia) meteorological station. According the empirical formulas, the calculations of vertical moisture exchange were made. The methodological basis of the work is the application of systematic and expert-analytical approaches to the organization of soil-ecological survey of the agrolandscape, with intensive anthropogenic impact, the development of ecologically safe two-way regulation of the water regime by irrigation and drainage, counting on vertical moisture exchange in the soil. The soil surveys, laboratory, field experiments, analytical researches and analyzes were carried out according to the methods of Shebeko (Shebeko *et al*., 1980), Rogotskiy (1981) and Pylenok (1985), as the basis of the crops water consumption calculation and vertical soil moisture exchange research:

$$V = 0{,}70B + 0{,}01 \quad (1)$$

where V - heat loss by evaporation, mJ.

According the calculation method (1) Mazhayskiy (2002) derived the water consumption (E):

$$E = K_{sp}^{B} \cdot n \quad (2)$$

$$E = K_{sp} \cdot d_{sr} \cdot n \quad (3)$$

where B is the radiation balance, mJ/m^2;
d_{sr} - average saturation moisture deficit, hPa;
K_{sp}^{B} K_{sp} - bioclimatic coefficients of water consumption of agricultural crops;
n - duration of the calculation period, day.

The relation for the calculation of vertical moisture exchange (Mazhayskiy, 2002):

$$\pm M = a\Delta D^{v} K_w^{c} e^{dH} n \text{ , mm/day} \quad (4)$$

where $\Delta D = (E\text{-}O\text{-}m)/n$ - water consumption deficit, mm/day;
$K_w = W_H/W_{HB}$ –relative soil moisture of the calculated soil layer,%;
H – depth of groundwater level from surface, m;
e – the base of the natural logarithm;
a, v, c, d - empirical coefficients;
O, m - precipitation and watering for the calculation period, mm;
W_H, W_{HB} - respectively, the actual soil moisture at the beginning of the period and at the level of the least water capacity,%.

The height of the capillary rise of moisture for sandy loam soils was taking into account, It was found that a noticeable recharge by groundwater of the root system of lupine is possible from a depth of 1.7 m, potatoes - 1.5 m, oats - 1.6 m. The vertical moisture exchange of the calculated soil layer with the underlying layers dependencies at ground water level depth 1.5–1.7 m (Mazhayskiy, 2002):

$$\pm M = a^1 \Delta D^{v1} K_w^{c1} e^{dH} n\,, \quad a^1 = a e^{dH}\,. \qquad (5)$$

According empirical formulas (4, 5) the calculations of vertical moisture exchange are made. The results were comparing with the actual data of lysimetric (variable and constant water level). Correlations between soil moisture in different depth were obtained.

RESULTS AND DISCUSSION

The water consumption were noted significant with total radiation, radiation balance and air humidity deficit (r = 0.85-0.64), significant with sunshine duration, temperature and humidity (r = 0.50-0.65), less stable - with wind speed, evaporation from the water surface, precipitation and soil temperature (r = 0.32-0.40) and are significant at a probability of 0.95-0.99. These values and characterizes the evaporation conditions per day more accurately in comparison with the average daily deficit. In turn, the radiation balance is significant correlated (r = 0.85-0.64) with the air humidity deficit, and then with the temperature and humidity of air. Thus, it is established that the fluctuation of water consumption of crops occurs synchronously throughout the day, and the maxima of these factors coincide with the true noon and occur at 2-3 pm in summer local time. Therefore, in the daily period, the relation between water consumption and radiation is linear in the phases of the crops development. The transition of the radiation balance from negative to positive values takes place an average of one hour after sunrise, and the reverse transition is observed in the evening, 1.5 hours before sunset. The water consumption coincides with the beginning and end of the sunshine. The duration of sunshine is largely a factor determining the radiation balance and the deficit of air humidity. The correlation coefficient is 0.99 between radiation balance and the heat costs was found. Uniform in biological development natural grass cover on the meteorological site with periodic underfeeding has a relatively constant water consumption. Therefore, the variability of the thermal factor- solar radiation has a significant effect on its dynamics, and the biological factor has a constant value. This increases the tightness of the connection and determines its linear nature. However, when analyzing the tightness of the connection between water consumption of potatoes and the radiation balance, a close relation can be traced only by periods of biological development. The features of intra-day dynamics of water consumption and meteorological factors and correlation analysis point to the existence of the water consumption connection both with the radiation balance and with a deficit of air humidity. Bioclimatic coefficients of water consumption of agricultural crops according (formula 2) and (formula 3) given in Table 1.

Table 1. Mean values of bioclimatic coefficients of the field crops water consumption

Culture	Indicators	Weeks from the time of field crops sowing (planting)							
		1	2	3	4	5	6	7	8
Lupine	K_{sp}^{B}	0.10	0.15	0.19	0.27	0.27	0.28	0.47	0.34
	K_{sp}	0.19	0.25	0.35	0.45	0.54	0.57	0.92	1.01
Potatoes	K_{sp}^{B}	0.10	0.10	0.15	0.23	0.25	0.30	0.32	0.35
	K_{sp}	0.15	0.17	0.27	0.31	0.53	0.53	0.68	1.42
Oats	K_{sp}^{B}	0.09	0.14	0.26	0.33	0.32	0.31	0.42	0.47
	K_{sp}	0.17	0.20	0.18	0.56	0.65	0.61	0.86	1.38
Culture	Indicators	Weeks from the time of field crops sowing (planting)							
		9	10	11	12	13	14	15	16
Lupine	K_{sp}^{B}	0.33	0.25	0.28	0.20	0.16	-	-	-
	K_{sp}	0.83	0.64	0.62	0.40	0.32	-	-	-
Potatoes	K_{sp}^{B}	0.27	0.31	0.35	0.30	0.26	0.22	0.28	0.11
	K_{sp}	0.86	0.70	0.73	0.62	0.62	0.42	0.45	0.19
Oats	K_{sp}^{B}	0.32	0.31	0.36	0.20	0.24	0.29	0.15	-
	K_{sp}	0.87	0.77	0.74	0.40	0.54	0.61	0.34	-

Note: K_{sp}^{B} K_{sp} - bioclimatic coefficients of water consumption of agricultural crops

The water regime of soil is largely formed under the influence of vertical moisture exchange in the aeration zone. The correlation ratio of the weekly values of the total moisture exchange in the aeration zone is: with the groundwater level - 0.44; moisture reserves at the beginning of the calculation period - 0.53; air temperature – 0.14; air humidity – 0.27; air humidity deficit – 0.33; water consumption – 0.38; the sum of precipitation and watering - 0.54; average daily water consumption for the calculation period - 0.60; the ratio of the average daily deficit of water consumption to relative moisture reserves in the calculated soil layer, expressed in fractions of least water capacity - 0.65 during the vegetative period of plants.

The relations between vertical moisture exchange, deficit of water consumption and soil moisture are curvilinear. Thus, during the periods of "flowering" and " tubers formation" of potato, the relations between vertical moisture exchange and water use deficit increases, the correlation ratio increases up to r = 0.86-0.92. The main determining factor for basin recharge is ground water level (r = 0.70-0.80), for infiltration - water consumption deficit (r = 0.60-0.90). An increase in basin recharge corresponds to an increase in the deficit of water consumption, a decrease in the moisture content of the root layer and the depth of groundwater. When irrigating these lands, vertical water exchange should be taken into account too, because on these conditions soil moisture exchange is different as the case of shallow depth of groundwater. The correlation between layers according formula (5) is 0.68-0.90 and the reliably at a probability of 0.95, 0.99. The obtained dependences can be used for water balance calculations of the water regime of

meliorated lands with deep groundwater occurrence. They are applicable at relative humidity of soil (K_w) = 0,5-2,0. Empirical coefficients for vertical moisture exchange calculation according (formula 4) and (formula 5) given in Table 2.

Table 2. Empirical coefficients for vertical moisture exchange calculation

Culture	ΔD	Sandy loam soil						
		Drained H <1.5-1.7 m				$H \geq$1.5-1.7 м		
		a	v	c	d	a^1	v^1	c^1
Lupin	>0	33.70	0.70	-1.95	-4.20	0.027	0.70	-1.95
	<0	0.32	0.34	1.92	0.10	0.379	0.34	1.92
Potatoes	>0	285.4	0.28	-3.92	-5.80	0.048	0.28	-3.92
	<0	0.32	0.34	1.92	0.10	0.372	0.34	1.92
Oates	>0	48.6	0.73	-2.79	-3.50	0.180	0.73	-2.79
	<0	0.32	0.34	1.92	0.10	0.376	0.34	1.92

Note: a, v, c, d - empirical coefficients

Taking into account the dependencies for determining water consumption and vertical moisture exchange for calculating the unsteady movement of groundwater according to the developed algorithm, water balance calculations were performed. It was found that on the drained sandy loam soil it is recommended to apply the formula (4) for vertical moisture exchange calculation, and at groundwater level H> 1.5 m for potatoes, H> 1,6-1,7 m for oats and lupines - formula (5). The vertical soil moisture exchange of the calculated soil layer should be taken equal to the deficit of water consumption with the opposite sign then H <0.5 m.

The biological features of the crops and the depth of the root system development significantly affect their values for sandy-loam soil. The regression coefficients for determining the negative component of vertical moisture exchange differ less significantly, as the moisture infiltration beyond the calculated layer of soil is a physical process. The groundwater levels in the calculations of the drained land according to the developed algorithm were dynamically (depending on the moisture content of the year) varied from 0.7 to 1.8 m. The oat uses the moisture of the underlying soil layers more fully. There is a significant moisture infiltration from the calculated soil layer into the underlying horizons on lands with a deep groundwater occurrence, so the total vertical moisture exchange is mostly negative. The values of vertical moisture exchange can be used in calculations of the soil water regime, in determining the value of irrigation norms and estimating the share of basin recharge in water consumption of plants. The results of the comparison show that the recommended method in this work gives the smaller errors in determining the vertical moisture exchange. The deviations of the calculated values from the actual ones vary from +5 to -12%.

CONCLUSIONS

Values of water consumption of agricultural crops and vertical moisture exchange in the soil in the regimes of water balance of agricultural reclaimed lands can be obtained only experimentally or as a result of calculations based on empirical relations. The values of the water consumption of irrigated crops (in the operational regime of irrigation in the calculation of the water balance) are recommended to be determined counting on: the indicators of heat supply of the territories, that is, the radiation balance; air humidity deficit and bioclimatic factors of water consumption, taking into account the type and phase of plants development, the physical condition and the soil moistening.

The empirical method for determining the vertical moisture exchange takes into account the biological characteristics of crops, the conditions for the heat and moisture availability of the calculation periods, the power and humidity of the soil layer under study, the water-physical properties of the ground, and the depth of the groundwater. It gives reliable results and can be used in calculations of the water regime in designing and exploitation the reclamation systems.

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MICROBIOLOGICAL CONTROL OF *CARPOCORIS FUSCISPINUS* (HEMIPTERA: PENTATOMIDAE), A PEST OF ONION AND LEEK SEED CROPS

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ABSTRACT

Any agricultural production requires the prior production of seeds, carried out by specialized companies, which own in-depth knowledge of seed crops as well as of their pathogens and pests. These pathogens and pests often remain unknown to the agricultural world. They are very little studied and control strategies do not exist. The present study is typical of such a situation: Zollinger Bio, an organic seeds producer, regularly deals with seed crops health problems. Over the last years, the production of seeds of onion (*Allium cepa*) and leek (*Allium ampeloprasum var. porrum*) has been reduced by 50% by a bug, morphologically and genetically identified as *Carpocoris fuscispinus*. Their piercing-sucking mouthparts allow these insects to empty the maturing seeds. *Carpocoris fuscispinus*, a native bug in Europe, has never been considered as a pest, although observed once as a cereal pest in Iran. The pest has already caused damage during flowering making the use of insecticides not possible, because of their harmful effect on pollinating insects. Entomophagous fungi could be an alternative. Two fungal isolates, *Beauveria bassiana* UASWS 1427 and *Paecilomyces fumosoroseus* UASWS 1457, were tested against *C. fuscispinus*. The experimental units consisted of five bugs in a box with water and food (leek flower, spelled crop seeds). The mortality increased quickly between day four and day eight and reached 100% adults for *B. bassiana* and 90% for *P. fumosoroseus* at day eight. Similar results were obtained on larvae. These results are promising of a possible microbiological control against *C. fuscispinus*.

Keywords: *Beauveria bassiana, Carpocoris fuscispinus, entomophagous fungi, organic agriculture, Paecilomyces fumosoroseus.*

INTRODUCTION

The production of any agricultural crop requires farmers to know what their plants need in order to grow. Additionally, they also need to know how to protect their plants from potential pests that could ruin their crops. Pests come in a multitude of shapes and sizes, be it tiny nematodes destroying root systems or bigger mammals grazing on crops. Over the last decades, a new group of pest has emerged and has become a growing problem in agriculture: stink bugs (Hemiptera: Pentatomidae) (Panizzi, 2015). These insects are the cause of many headaches for several reasons. First, most stink bugs are generalists, which means that they have a wide range of host plants that they can feed from (Lee et al., 2013). Species like the Brown marmorated stink bug (*Halymorpha halys*) or the Southern green stink bug (*Nezara viridula*) have been observed on over 100 different plant hosts (Kamminga et al., 2012; Rice et al., 2014). If no suitable host plant is available, stink bugs can adapt on a short time scale and feed on plants that were not part of their diet (Panizzi, 2015). Second, stink bugs seem to be more resilient to pesticides than other insects. Several studies testing the survival rates of different stink bug species after being exposed to synthetic insecticides commonly used in agriculture show that the mortality rates are often not convincing. Stink bugs also seem to be able to rapidly develop resistances against some insecticides (Castellanos et al., 2018; Tugwell et al., 2017). Insecticides that are homologated for organic agriculture (according to Swiss standards) perform fair no better than their synthetic counterparts and don't achieve a convincing mortality rate as well (Joseph, 2018; Kamminga et al., 2009).

A Swiss organic seed production company has also observed the emergence of a new stinkbug pest. Starting in 2017, seed harvest of onion (*Allium cepa*) and leek (*Allium ampeloprasum var. porrum*) has drastically dropped by 50 percent. A closer inspection of the two crops in the following years has shown that a stinkbug, identified later as *Carpocoris fuscispinus*, was feeding on maturing seeds. Using their rostrum, the stinkbugs systematically pierced through the maturing seeds and sucked the contents out, leaving an empty pulp behind. *Carposcoris fuscispinus* is native to Switzerland, with a wide distribution area across Europe and the Middle East (Lupoli et al., 2013). The stinkbug is not considered a pest in Europe, but some reports from Iran mention *C. fuscispinus* as being a minor pest of cereals (Hassazadeh, et al. 2009). No records mention any feeding on onions or leeks. Since the feeding damage occurs during or shortly after the crops bloom, many pollinators are present on the fields. Due to this, commonly used insecticides homologated for organic agriculture (neem, pyrethrin, spinosad) could not be used to control *C. fuscispinus*, as they would have had harmful non-target effects on these pollinators (Lopes et al., 2015; Miles, et al., 2012; Soni, 2014).

Bearing in mind the poor efficacity of insecticides against stinkbugs and the effects they would have on non-target pollinators, a new solution had to be sought in order to control the pest and reduce harvest loss. Microbiological control methods, such as the use of entomophagous fungi, seemed to be an interesting alternative that could solve the issues encountered with insecticides (Gouli et al., 2012; Ihara et al., 2001; Todorova et al., 2002)

The goal of the present study was to test the mortality rate of nymphs and adults of *C. fuscispinus* after being exposed *in vitro* to two entomophagous fungi strains, *Beauveria bassiana* (UASWS[1] 1427) and *Isaria fumosorosea* (UASWS 1457), applied at two different concentrations, 10^7 and 10^8 conidia per millilitre.

MATERIAL AND METHODS

The two fungal strains, *B. bassiana* and *I. fumosorosea*, were selected because their virulence was successfully tested in a previous research (Eckert, 2017). Fungal strains were cultivated in 96 mm Petri dishes on diluted Sabouraud medium (2% agar instead of 4%) with 0.3% chitin. Petri dishes were kept in a dark incubator at 24°C and fungi were transplanted once a month into fresh medium. After sporulation, conidia were extracted from the Petri dishes using a solution of distilled water and Tween®20 (0.4%) and were stored in a sterile flask. Conidia concentration was then calculated for each strain using a Thoma counting cell. Based on these concentrations, the initial solutions were diluted by factors six and seven in order to perform a viability test. For each strain and solution, three 96 mm Petri dishes of diluted Sabouraud medium were inoculated and were kept in a dark incubator at 24°C. Sporulation was analysed after three days.

In order to test the mortality rate of the stinkbugs, two solutions containing 10^7 and 10^8 conidia per ml were created for each fungi strain. A control solution consisting of distilled water mixed with Tween®20 at 0.4% was also created. These treatments were named $Bb10^7$, $Bb10^8$, $If10^7$, $If10^8$ and C. The solutions were tested on nymphs of the 2nd and 3rd instar as well as on adults.

For the nymphs, each experimental unit consisted of five nymphs, reared in the laboratory, placed in a 30 mm Petri dish. A 30 mm filter paper soaked with 100 µl of sterile water was placed at the bottom of each Petri dish in order to provide moister. Five leek flowers were placed in the Petri dish as well. Three experimental units were assigned for each of the five treatments (2 strains*2 concentrations+control). Nymphs were inoculated by applying 2 µl of the treatments onto their abdomen. Experimental units were kept in climatic chamber. Mortality of the nymphs was noted on D+1, D+4 and D+7. Sporulation was noted on dead nymphs seven days after death. Kruskal-Wallis test was applied in order to compare the mortality rate of the nymphs and the sporulation rate to the control at a significance level of 10%.

For the adults, each experimental unit consisted of five adults placed in a plastic box (10*8*6 cm) with a perforated cover. Adults were captured 10 days prior to the experiment and kept in a rearing cage. Each experimental unit was provided with a watering station, a leek flower head and a maturing spelt ear. Food and water were replaced every three days. Adults were inoculated by submerging five insects at a time in 20 ml of each treatment suspension for 10 seconds. Three experimental units were assigned for each of the five treatments (2 strains*2 concentrations+control). Experimental units were kept in a climatic chamber.

[1] UASWS: University of Applied Sciences Western Switzerland

Mortality of the adults was noted on D+1, D+2, D+3, D+4, D+5, D+8, D+9, D+12 and D+15. Sporulation was noted on dead adults 14 days after death. Kruskal-Wallis test was applied in order to compare the mortality rate of the adults and the sporulation rate to the control at a significance level of 10%.

RESULTS AND DISCUSSION

On D+7, mean mortality rate for the nymphs were 100% for $Bb10^7$, 93% for $Bb10^8$, 86% for $If10^7$ and $If10^8$, and 53% for the control (Fig. 1). Mean mortality rose faster for $Bb10^8$ during the first four days of experiment than for the other treatments. P-Value on D+7 was 0.045 and median mortality rate was significatively different from the control for $Bb10^7$.

Mean sporulation rate of dead nymphs after 10 days was 80% for $Bb10^7$, 83% $Bb10^8$, 0% for $If10^7$, 16% for $If10^8$ and 0% for C. Sporulation of *B. bassiana* were noticed three days after nymphs died.

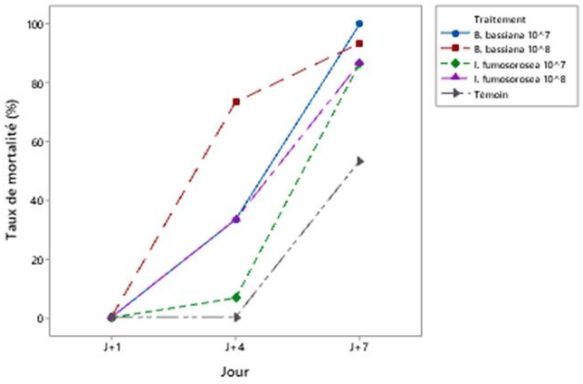

Figure 1. Mean mortality rate of nymphs over one week

For the adults, mean mortality rate on D+15 was 100 % for $Bb10^7$, $Bb10^8$ and $If10^8$. For $If10^7$ it was 93% and 46% for C (Fig. 2). Mean mortality rate increased mostly between D+4 and D+8 for the fungi treatments. Mean mortality rate for the control was high since the first day of experiment and evolved slowly over the next two weeks. On D+15, P-Value was 0.022. Median mortality rate was significantly higher, with a 95% certainty, for $Bb10^7$, $Bb10^8$ and $If10^8$ compared to C. Mean sporulation of dead adults after 14 days was 100% for $Bb10^8$, 93% for $Bb10^7$ and $If10^7$, 86% for $If10^8$ and 8% for C (Fig. 3). One adult from the control treatment sporulated.

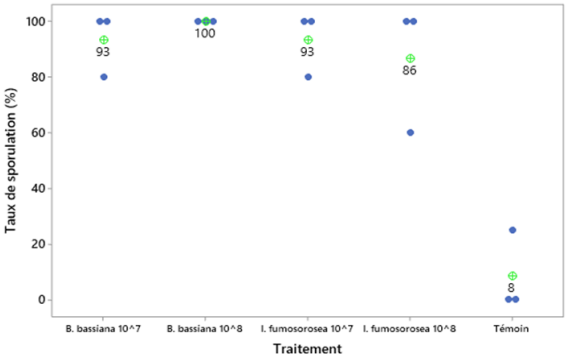

Figure 2. Mean mortality rate of adults over two weeks

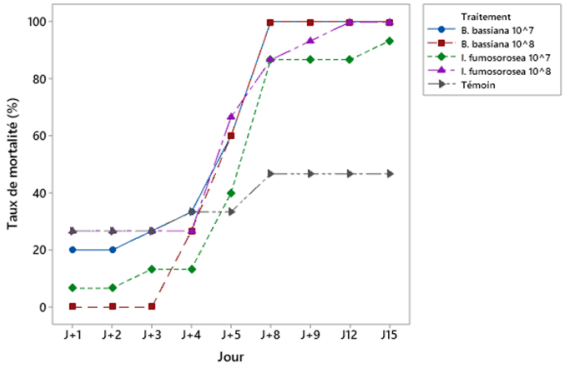

Figure 3. Sporulation rate of each experimental unit (blue) and mean sporulation rate (green)

These results show, that the fungal strains *B. bassiana* (UASWS 1427) and *I. fumosorosea* (UASWS 1457) can infect the stink bug *C. fuscispinus* in laboratory conditions. Sporulation on insects showed that both strains can successfully reproduce themselves in this host and create new conidia. The high sporulation rate observed on adults could indicate that mortality is mainly caused by the entomophagous fungi used in this experiment. This could also be the case for the nymphs treated with *B. bassiana* at both concentrations, were mean mortality and mean sporulation are high. On the other hand, mean mortality of nymphs was high for both *I. fumosorosea* treatments, but sporulation was low or completely absent. After day four of the experiment, a gradual drying out of the filter paper that was at the bottom of the 30 mm Petri dishes was noted. Since nymphs inoculated with *I. fumosorosea* seemed to die after day four, sporulation would have occurred in drier conditions than it occurred for *B. bassiana* which sporulated during the first four days of experiment. Several sources claim that sporulation of entomophagous fungi depends strongly on water availability (Arthurs & Thomas, 2001; Borisade, 2018).

This could explain why mortality rate of both *I. fumosorosea* treatments was higher compared to the control and why sporulation was low.

Mortality rate of the control was an important issue in this experiment. The nymphs were reared in laboratory conditions and were thus formed a homogenous population. Mortality appeared after day four, when the filter paper started to dry out. The mortality could result from this lack of moisture. In further experiments, this issue should be addressed in order to get better results. For the adults, laboratory rearing proved to be difficult and wild insects had to be collected in order to conduct the experiment. The population used for the test was thus not homogenous, which could explain the high mortality rate.

CONCLUSIONS

The emergence of this pest shows that new control methods have to be studied in order to protect crops. This experiment showed that the two tested entomophagous fungi strains, *B. bassiana* (UASWS 1427) and *I. fumosorosea* (UASWS 1457), could potentially be interesting solutions to control the stink bug *C. fuscispinus*. Mortality rates were high for adults and nymphs for both fungi at concentrations of 10^7 and 10^8 conidia per ml. Since both fungi could reproduce and create new conidia, these entomophagous fungi could potentially infect new individuals and thus protect crops over longer periods.

Even though these first results look promising, further experiments have to be conducted. The effectivity of both strains has to be tested in an *in situ* experiment, for evaluating their potential in a less controlled environment.

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EFFECTS OF BROWSING PRESSURE ON THE TEXTURAL CHARACTERISTICS OF *JUNIPERUS COMMUNIS* L. BRANCHES

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ABSTRACT

In the Montseny Natural Park junipers scattered in the grasslands can be found. In some of these areas of the park, the breeding of small ruminants is allowed, while in others only find wildlife exists. Junipers develop differently if browsed, adopting spherical or conical morphotypes. This paper studies the mechanical characteristics of the shoots according to the sex of the bush and the branching regime to which they are subjected. 729 individual shoots were taken from male and female junipers exposed to browsing from goats and ewes and those not grazed and sampled at a different position from each bush. All the leaves were taken off the non-lignified end of the shot to be studied by a simulated bite. The strength needed to cut the apical twigs of junipers was measured using a Volodkevich jaw, which mimics the way incisors act, using a texturometer. The diameter of the branches differs according to bushes' sex being larger for females and the individuals not exposed to predation pressure. Although the differences induced by sex were significant, differences due to grazing pressure were larger. The annual branches were thicker and longer in non-grazed junipers. This difference was not due to the partial consumption of the studied branches, as all the samples were collected in full. The continued browsing pressure leads to a survival strategy of growing, with branches tighter packaged as was evident in the analysis of the branching structure. The longer annual branches in non-grazed bushes allow for a more open structure. The force necessary to break the branch was significantly higher on females. This could be related to the fact that the females must bear the weight of the fruits. The elasticity of the annual shots was significantly higher on non-grazed junipers, a fact that could be considered as a way to tolerate herbivory.

Keywords: *sex dimorphism, small ruminants, juniper, grazing, morphotype.*

INTRODUCTION

Studies of plant-herbivore interactions have had a major focus of interest in the chemical defences that plants develop in the form of secondary compounds (Haukioja, 1991; Strauss and Agrawal, 1999) and how herbivores adapt to them. Some works have also addressed the role of physical defences such as spikes

and thorns (Cooper and Owen-Smith, 1986). But plants also may limit herbivory by producing hard, rigid leaves and stems that are difficult to chew. These physical plant traits can reduce the performance and productivity of herbivores by reducing ingestion or increasing the time necessary to obtain enough energy. However, the information on physical plant strategies of tolerance to defoliation is remarkably scarce.

Juniper (*Juniperus communis* L.) is a species characterized by having a high content of secondary metabolites (Butkienë et al., 2015), which can be considered as chemical constitutive defences. However, resistance may not be a viable strategy if the resistant species are eventually defoliated (Augustine and MacNaughton, 1998) what happens in the case of juniper browsed by goats and sheep (Bartolomé et al., 1998). It is also necessary for these species to have a certain degree of tolerance to defoliation. Tolerance is defined by having traits that enable plants to recover from herbivory. Some of these traits are the ability to increase branching or, as in the case of juniper, adopt structural morphotypes that reduce the consumption capacity of herbivores (Strauss and Agrawal, 1999). Besides, these traits can be induced, which means they increase after herbivory (Haukioja, 1991). Another aspect to consider is that juniper is a dioecious species, therefore the response to herbivores could be different depending on the sex of the plant (Cornelissen & Stiling, 2005).

The aim of this study was to evaluate and compare the re-growth traits of browsed induced morphotypes of juniper in order to determine their tolerance to herbivory and if that tolerance is different according to the sex of the individual.

MATERIALS AND METHODS

Study area

Montseny massif (1,707 m a.s.l.) is located in Catalonia, NE of Iberian Peninsula, in the Mediterranean region, and known throughout the world for the beauty of its landscapes. Its abrupt relief, surrounded by streams and ridges, results in an extraordinary variety of habitats that had led to be considered one of the UNESCO biosphere reserves. The climate at the highest points is temperate with an average annual temperature of 7 °C and an average annual precipitation of 1,000 mm. Broadly speaking, the Montseny area presents three ecosystems organized according to altitude. The lower parts of the mountain, up to 900 m, are the domain of Mediterranean vegetation, especially holm oak (*Quercus ilex*) and its accompanying species. Euro-Siberian vegetation, with beech (*Fagus sylvatica*) and patches of fir (*Abies alba*) forests, extends from 900 to 1,600 m. Finally, subalpine dwarf shrub heathlands with heather (*Calluna vulgaris*), and juniper (*Juniperus communis*) and intermixed grasslands are present above 1,600 m but also in cleared patches of Euro-Siberian vegetation. This has been a mountain ridge heavily dedicated to human uses, and although now having a protection status and suffering the regression of agricultural, forestry and livestock activities, there is still a shared use with the protection of natural spaces.

In the Montseny peaks and altiplanos, subalpine grasslands are common. Juniper is one of the shrub species that currently colonize pastures due to the prohibition of fire in protected natural areas. Flocks of goats and sheep use daily the pastures for grazing (Bartolomé et al. 1998) and also browse on the scattered shrubs like juniper causing morphotypes in the shape of a sphere or cone less than a meter tall. In areas where grazing is not allowed, junipers develop in their typical flame shape several meters high.

Textural analysis

Apical shoots from 10 male and 10 female junipers corresponding to grazed and not grazed bushes were collected to study the force needed to cut the shot. The apical shots collected were all intact ones.

The force necessary to cut the juniper apical branches was measured by texturometer TA-XT attached to Volodkevich bite jaws, to simulate the action of the front incisor teeth and enables a cross-section of the sample, up to 1 cm, to be measured. The bite was done at 5 mm/s until the branch was cut. Measurements were repeated each 2 mm through all the length of the non-lignified part of the branch. The lengths of each shoot and its average diameter were recorded. A typical graph of force vs time for this bite imitation essay can be seen in Figure 1.

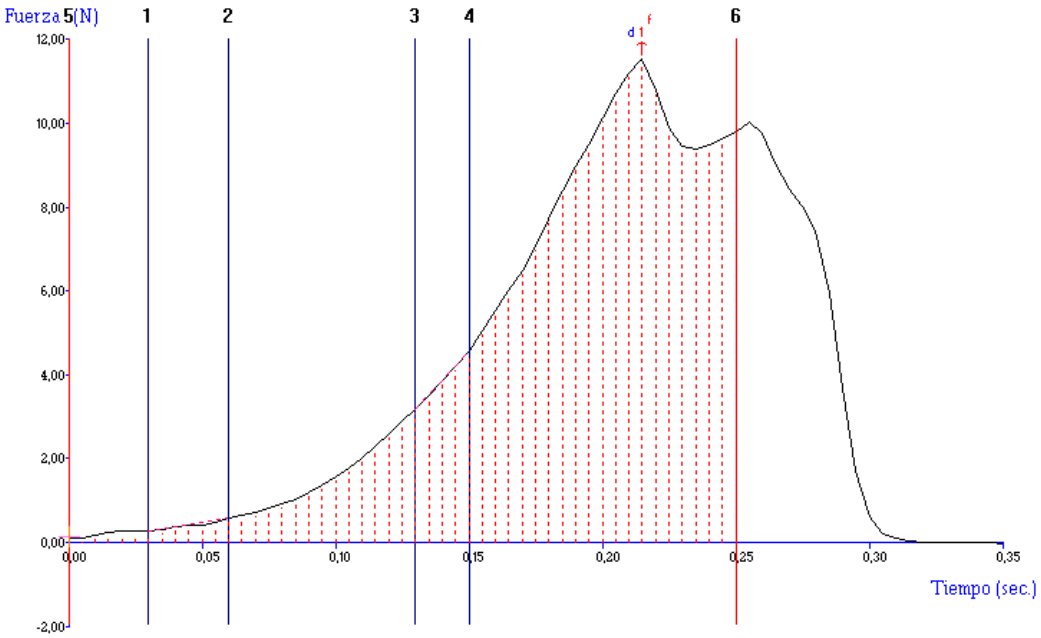

Figure 1. Example of a force-time curve corresponding to the cutting of annual shots of junipers between Volodkevich bite jaws.

From the recorded force-distance some variables were derived:

- The elasticity at low deformation, as the slope in the initial part of the curve, between 10-25 % deformation (points 1-2 in figure 1)
- The elasticity at high deformation, as the slope of the force/deformation curve before fracture, between 55-65 % deformation (points 2-3 in figure 1)
- The maximum force
- The distance of deformation at the point of maximum force (this distance is different from the thickness of the sample was fracturable)
- The work of the bite (area under the curve from the beginning of the test up to point 6, in figure 1)

Statistical analysis

729 individual measurements were made, studying 5 branches of any of the 20 individual junipers considered. The measured variables on each sample were subtitled to GLM procedure, analysing the parameters of sex and exposure to grazing and its interactions. Statistical differences between means were evaluated by means HSD test for an unequal number of observations at a p-value of 0.05.

RESULTS AND DISCUSSION

The diameter of the branches differs according to bushes sex (1.28 mm for females and 1.18 for males) and for predation pressure (1.15 for grazed bushes and 1.28 for non-grazed), as was the length (3.77 cm for females and 3.42 cm for males) (2.96 cm for grazed and 4.12 cm for non-grazed). Non-grazed bushes have a more open structure, while the individuals exposed to the activity of herbivores are more compact as a result of clipping of the growing annual shots and probably as a strategy to tolerate depredation. This browsing does not occur all year round, as during spring and summer the pastures are available and become the preferred source of feed. But in winter, when grasses are scarce, the herbivores graze on bushes such as junipers (McGowan, Joensalo and Naylor, 2004).

Female bushes produce significantly shorter branches. This inversion in vegetative growth can be expected, as usually females have to invest in reproduction more than males and thus have less remaining energy for vegetative growing. Whilst the differences by sex were significant, differences due to grazing pressure were larger. Although Stark and Martz (2018) found an increase in juniper biomass one year after pruning the young branches, this effect was not found in our study, probably due to continuous grazing effect. Cornellisen and Stiling (2005) detected in their metanalysis a tendency to longer shots in males exposed to herbivory, in coincidence with our results. The annual branches were thicker and longer in non-grazed Junipers. This difference was not due to the partial consumption of the studied branches, as all the samples were collected in full. The continued predation pressure leads to a survival strategy of growth, in which the animal would be forced to consume smaller shoots and consequently invest more time to satisfy its feeding needs.

On grasslands, the continuous pressure on bushes delays the ecological succession toward the forest, and an example is a reduction in the size of junipers on pasture lands. A similar pattern was observed on another species of juniper (*Juniperus macrocarpa*) on Doñana National Park (Muñoz-Reinoso, 2017).

On the measured textural characteristics presented in Table 1, most were the same for male and female junipers, as we may expect as morphological differences between sexes are scarce. However, the force necessary to break the branch was significantly higher on females (24.0 N against 22.0 N on males) and the depth of the bite was large (1.25 mm against 1.14 mm on males). This difference on the extension on the bite necessary to break the branch was partly related with the differences in size, but also was reflected on the average of samples that break before the incisors cut all the branch thickness (odds of 0.39 in front of 0.43 for males).

Table 1. Values of the parameters extracted from biting juniper branches (mean and standard deviation). Values in the same row with the same letter do not differ at p=0.005

	Browsed		**Non-browsed**	
	Male	**Female**	**Male**	**Female**
Length (cm)	2.77 ± 0.55 [a]	3.12 ± 0.52 [a]	4.09 ± 0.77 [b]	4.14 ± 0.79 [b]
Thickness (mm)	1.11 ± 0.17 [a]	1.19 ± 0.22 [a]	1.23 ± 0.26 [a.b]	1.36 ± 0.21 [b]
Modulus (low deformation)	14.6 ± 2.9 [a]	15.6 ± 5.2 [a]	16.4 ± 4.7 [a]	15.8 ± 6.6 [a]
Modulus (high deformation)	75.6 ± 9.6 [a]	84.3 ± 17.8 [a.b]	94.7 ± 20.0 [b]	89.0 ± 16.1 [a,b]
Breaking force (N)	19.1 ± 5.2 [a]	21.7 ± 5.1 [a.b]	22.8 ± 4.0 [b]	24.6 ± 3.8 [a,b]
Work (mJ)	1.77 ± 0.53 [b]	2.16 ± 0.72 [a.b]	2.30 ± 0.65 [a]	2.56 ± 0.46 [a]
Fracturability	0.36 ± 0.22 [a]	0.40 ± 0.22 [a]	0.50 ± 0.23 [a]	0.47 ± 0.29 [a]

The elasticity of the annual part of the branches was significantly higher on non-browsed junipers, accounting for 94 N/s when compared with 81 N/s on grazed bushes for 55-65% deformation (188 N/s and 167 N/s for 75-90% deformation, respectively). The higher force necessary to cause deformation to suggest a stronger structure may be more lignified. The force necessary to break the branch with the incisors correlated with the slope of the force-deformation curve, and was

higher for non-grazed bushes (24.3 N in front of 20.9 N for grazed junipers), the same as the distance necessary to achieve such a breaking (1.24 mm compared with 1.13 mm for non-grazed and grazed, respectively). The higher force and larger deformation correspond with a higher force to cut, being 2.46 for non-browsed and 2.01 for foraged. A 44% of branches from the non-browsed break before reaching the full bite depth, while only 36% did it on predated junipers.

CONCLUSIONS

Browsing pressure on bushes, lead to changes in morphology and the textural/cutting characteristics of the apical shots, but not in the line of hardening the shoots but in reducing their size and probably varying their spatial distribution. These changes made the junipers more tolerant to the activity of herbivores. Although some differences can be attributed to sex, the main cause of the difference between individuals is exposure to grazing.

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ANTIBACTERIAL AND ANTIOXIDANT ACTIVITIES OF THE ESSENTIAL OIL OF CUMINUM CYMINUM SEEDS

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ABSTRACT

Cuminum cyminum (in arabic: Kemoun) is an important source of therapeutic, cosmetic, bio-food and technological agents. Ancient civilizations used this plant for therapeutic purposes. Extracts from this plant are nowadays strongly used in the industrial and research fields, particularly for the medicinal, pharmacological and cosmetological purposes. Bioactive molecules extracted from *Cuminum cyminum* may express biocidal activities and prove to be good candidates for new antioxidants. The objective of the present work is to evaluate the biological properties of this plant, including antibacterial and antioxidant effects. The seeds of cumin are harvested at the wilaya of Biskra, and stored in a dry place until their use. They were identified at Hassiba Benbouali University of Chlef. Essential oil is obtained by hydro-distillation using a Clivenger type device (AFNOR, 2000). The obtained sample is stored in sealed bottles at low temperature (4°C) and away from light. The antibacterial effect is assessed by the disc method. The minimum inhibitory concentration (MIC) is determined by standard methods. The antioxidant activity is evaluated by the DPPH free radical trapping method of the methanolic extracts. The essential oil of *C. cyminum* shows a better activity against Gram+ strains compared to Gram- strains. The determination of MICs leads to the conclusion that its activity can be triggered at a very low concentration. The reaction with DPPH gives an interesting IC50. This testifies to the ability of this essential oil to reduce free radicals. Thanks to the antibacterial activities that we have highlighted, cumin can be considered as a palliative that could replace certain antibiotics. Moreover, its antioxidant activity allows us to use it as a natural food additive.

Keywords: *Cuminum cyminum, antibacterial and antioxidant activities, Minimum inhibitory concentration, IC50.*

INTRODUCTION

Plants have therapeutic properties and valuable characteristics that have been passed down from generation to generation or are kept in old scrolls. The

phytotherapeutic, antimicrobial and antioxidant properties are triggers for intense industrial and research activity (Mohammedi, 2006).

Cuminum cyminum (in Arabic: Kemoun) is an important source of therapeutic, cosmetic, bio-food and technological agents. Ethnopharmacological data show that ancient civilizations used this plant for therapeutic purposes. Extracts of this plant are nowadays widely used in the industrial, and research fields and, in particular, in the medicinal, pharmacological and cosmetological fields. Bioactive molecules extracted from *Cuminum cyminum* may express biocidal activities and are good candidates for new antioxidants (Gachkar et al., 2007).

The objective of this work is to assess the biological properties, in particular the antibacterial and antioxidant properties of the essential oil of this plant.

MATERIAL AND METHODS

Seed harvest. The seeds are collected from the wilaya of Biskra (south of Algeria), and stored in a dry place until they are used. They were identified at Hassiba Benbouali University in Chlef.

Obtaining essential oil. The choice of the process for obtaining essential oil (EO) is generally limited by the standards linked to its use. The technique of exploiting the plant material can have a noticeable influence on the final composition of the essential oil (Piochon, 2008). In our study, essential oil is obtained by hydro-distillation using a Clivenger type device (AFNOR, 2000). The obtained sample is stored in tightly closed bottles at low temperature (4° C) and protected from light.

Evaluation of the "in vitro" antibacterial effect. The disc method is used to examine the antibacterial effect, which is measured by the diameter of the area of inhibition (Piochon, 2008). The paper discs are impregnated with the substance to be tested, then they are placed on the surface of an agar uniformly seeded with suspensions of five frequent strains (*E. coli, K. pneumoniae, S. aureus, P. aeruginosa, S. typhi*), maintained by subculturing on nutritive agar. The bacteria inhibition phenomenon results in clear areas around the discs.

Evaluation of the minimum inhibitory concentration (MIC). The method described by Remmal et al. (1993) and Satrani et al. (2001) makes it possible to determine the minimum inhibitory concentrations (MIC) of essential oils. To induce an effective germ/compound contact, a 0.2% agar solution with the dilutions: 1/10, 1/25, 1/50, 1/100, 1/200, 1/300 and 1/500, is used and poured into test tubes each containing 9 ml of agar medium sterilized in an autoclave (20 min at 121° C) and cooled to 45° C. Then 1 ml of these dilutions is added in order to obtain the following concentrations: 1/100, 1/250, 1/500, 1/1000, 1/2000, 1/3000, 1/5000 (v/v). Controls are prepared with the same agar solution alone. The seeding is done by streaks using a calibrated platinum handle. Incubation is carried out at a temperature of 37° C and away from any light source for 24 hours. In order to minimize the experimental error, each test is repeated three times.

Evaluation of the antioxidant effect of essential oils. The antioxidant activity is evaluated by the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical trapping method of methanolic extracts (Brand-Williams et al., 1995). To the primary

solution, 50 µl of each methanolic solution of the EO is added at different concentrations **(**from 1 to 5 mg/ml**)** and 5 ml of the methanolic solution of DPPH (0.004%). In parallel, a negative control is prepared by mixing 50 µl of methanol with 5 ml of the methanoic solution of DPPH. The positive controls are butyl-hydroxy-toluene (BHT) as well as ascorbic acid. The absorbance was read by spectrophotometry against a blank prepared for each concentration at 517 nm after 30 minutes of incubation in the dark and at room temperature. The antioxidant activity is evaluated according to the following equation:

$$\%\,\text{antioxidant activity} = \frac{\text{Abs}_{\text{control}} - \text{Abs}_{sample}}{\text{Abs}_{\text{control}}} \times 100$$

where Abs means Absorbance. By plotting the percentage of inhibition as a function of the concentration of essential oil, the inhibitory concentration of 50% of DPPH (or IC50) is calculated therefrom (Braca et al., 2001).

RESULTS AND DISCUSSION

Antibacterial effect. The appearance of zones of inhibition around the discs reflects the activity of the essential oil on the pathogenic strains tested. The diameters are variable depending on the strain tested (Remmal et al., 1993). Research of Oussalah et al., (2007) proved that essential oils have a specific and variable activity depending on the strain. Figure 1 shows the results of the activities of two antibiotics (nalidixic acid (NA) and co-trimoxazole (Co)) compared to those of the essential oil of *Cuminum cyminum*.

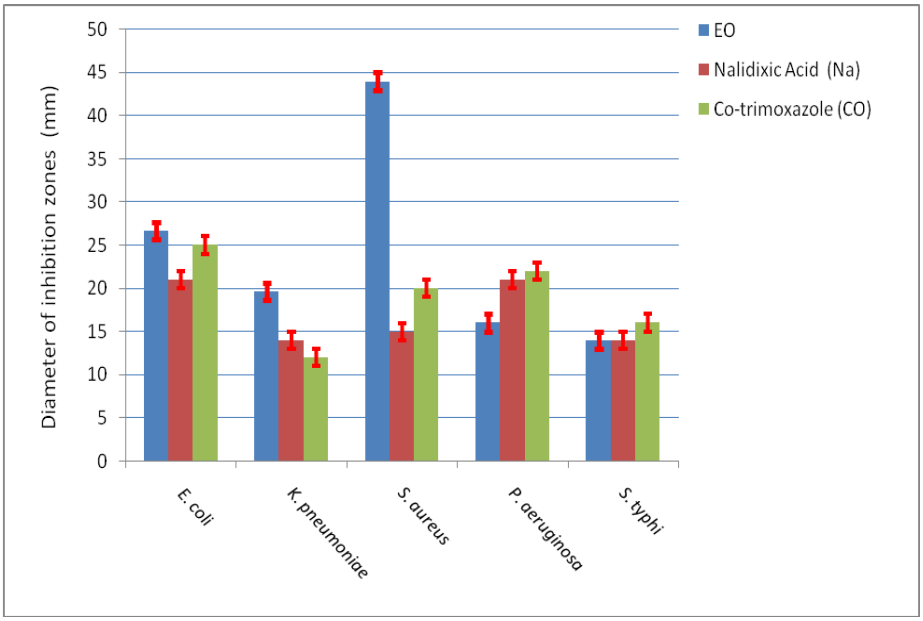

Figure 1. Average diameters of the inhibition zones of the bacterial strains with respect to the EO of *C. cyminum* and antibiotics.

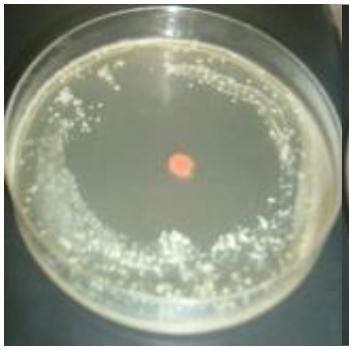

Figure 2. Effect of the EO of *C. cyminum* on *S. aureus.*

Figure 3. Effect of the EO of *C. cyminum* on *E. coli.*

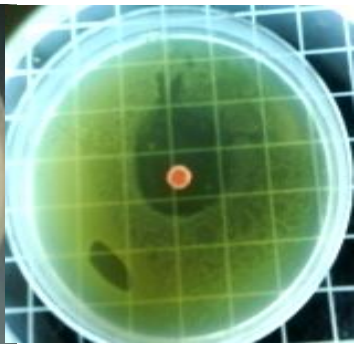

Figure 4. Effect of the EO of *C. cyminum* on *K. pneumoniae.*

Table 1. shows the different minimum inhibitory concentrations of *C. Cyminum* essential oil on the different strains tested.

Table 1. Minimum inhibitory concentration of the essential oil of *Cuminum cyminum*

Dilutions (v/v) Strains	**Wiitness**	**1/100**	**1/250**	**1/500**	**1/1000**	**1/2000**	**1/3000**	**1/5000**
E. coli	+	-	-	-	-	+	+	+
S. aureus	+	-	-	-	-	-	-	-
K. pneumoniae	+	-	-	+	+	+	+	+
P. aeruginosa	+	-	-	-	+	+	+	+
S. typhi	+	-	-	+	+	+	+	+

Growth +, Inhibition -, v /v: volume ratio of EO to agar solution.

Antioxidant effect. Table 2 presents the IC50 values of this essential oil compared to ascorbic acid and BHT.

Table 2. IC50 values for the essential oil of *Cuminum cyminum*, BHT and ascorbic acid.

Witness IC50 (mg/ml)		**Sample**
BHT	Ascorbic acid	EO of *Cuminum Cyminum*
$0{,}788 \pm 0.1$	$4{,}424 \pm 0.1$	$0{,}318 \pm 0.1$

Figures 1 to 4 show that the essential oil of *C. cyminum* expressed a very good antibacterial activity, with diameters of the inhibition zone ranging from 11.66 to 44mm. Furthermore, it is observed that the inhibitory effect is greater on *S. aureus* (Gram +) than on the other two bacteria (Gram -).

According to Oussalah et al., (2007), the efficiency threshold or minimum inhibitory concentration (MIC) is defined as the lowest oil concentration capable of inhibiting microbial growth. Therefore, the possibility of using a lower concentration of essential oils is desirable not only to avoid possible toxic effects, but also to benefit from their antimicrobial effects while reducing operating costs since their extraction costs are relatively high.

The essential oil of *C. cyminum* expressed an important inhibitory activity against bacterial strains (Table 1). Thus, it has been shown to be very effective against *S. aureus* at a concentration of 1/5000. *E. coli* was inhibited at a concentration of 1/1000 and *K. pneumoniae* at 1/250.

Furthermore, it is observed that *S. aureus* (Figure 1 and Figure 2) is the most sensitive among the bacterial strains with an average diameter of 44mm, followed by *E. coli* (Figure 3) and *K. pneumoniae* (Figure 4) with average diameters of 26.66mm and 19.66mm respectively.

According to Chami, (2005), the highest inhibitory concentration recorded in vivo by the EO of cumin is 1/250 and is therefore much lower than the toxic concentration (1/200 v/v). According to Hammer, (1999) and Dorman et al., (2000), the membrane permeability of Gram + and Gram- bacteria is a determining factor which explains the action of these oils.

As for the antioxidant activity of the EO of cumin, it is expressed in IC50. This EO has a capacity to reduce the free radical. The concentration required for neutralization and stability of 50% of the concentration of DPPH is 0.318 g/l. From this result, it can be said that the essential oil of cumin has a very important antioxidant activity and superior to that of ascorbic acid and BHT (Table 2).

The comparison of the IC50 of the EO of *Cuminum Cyminum*, *Citrus ladaniferus* [948.06 µg/ml] and *Lavandulastoechas* [1852µg/ml]) (Mohammedi, 2006), showed that the former has a higher antioxidant activity than that of the other two plants. Gachkar et al. (2007), noted that the antioxidant activity differs depending on the test used. Rosemary essential oil is better than cumin in the DPPH free radical scan, while cumin is better when the β-carotene bleaching test is used. The antioxidant activity of EO is attributed to certain alcohols, ethers and ketones (Piochon, 2008). EOs which contain phenolic compounds have remarkable antioxidant properties (Brand-Williams et al. 1995).

Finally, it should be noted that there are several published studies indicating a relationship between the long-term intake of synthetic antioxidants and some health issues, such as skin allergies, gastrointestinal tract problems and in some cases increased the risk of cancer (Lourenço et al., 2019). Plants are potential sources of natural antioxidants such as ascorbic acid, tocopherol, carotenoids, flavonoids and phenolic acids (Hatami et al., 2014). This explains the enthusiasm of manufacturers to improve techniques for extracting essential oils from plants (Stratakos et al. 2016, Arslan et al. 2017, Zhenfeng et al. 2019).

CONCLUSIONS

The study that we conducted through the extraction and analysis of the essential oil from seeds of *Cuminum cyminum* allowed us to establish a certain number of conclusions:

* The essential oil of *C. cyminum* showed excellent activity with respect to Gram + strains compared to those with Gram-.

* The determination of MIC allowed us to deduce that the studied antibacterial activity of essential oil can be triggered at a very low concentration.

* The reaction with DPPH yielded an IC50 = 318.47 μg/ml. This essential oil has ability to reduce free radicals.

For this purpose, the essential oil extracted from cumin can be considered as a medicine (which can replace, at least partially, antibiotics) but must obey a strict medical prescription in order to benefit from its therapeutic contribution. It can be used as a preservative additive in foodstuffs without altering its organoleptic properties due to the low MICs. Another virtue, no less negligible, is their volatility which allows them, as sanitation and preservation of air quality products in the processing and storage of food products, to reduce the risk posed by chemicals commonly used.

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SMALLHOLDER FARMERS' RESOURCE ALLOCATION DECISIONS IN A MAIZE-FARMING SYSTEM UNDER CLIMATE RISKS IN MALAWI

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ABSTRACT

Using household data from Lilongwe districts, along with crop phenology, agronomic management and climatic data from Chitedze Research Station, the Target-MOTAD and DSSAT-CSM models examined the resource allocation decisions of smallholder farmers in maize farming systems under climate risk in Malawi. Specific aims were to evaluate the ability of DSSAT to predict and collate DTM and non-DTM yields under climatic risk and to use a bio-economic procedure developed using DSSAT and Target-MOTAD to explore the impact of climatic risk on allocation of resources to DTM and non-DTM production. The paper argues that higher average yields observed from DTM varieties make it the most optimal maize production plan, in maximizing household incomes, food security, and minimizing deviations from the mean while meeting the set target incomes of farmers compared to non-DTM varieties. The multidisciplinary nature of this paper has contributed to the body of research by providing a powerful analytical procedure of modelling farmers' resource allocation decisions in maize based farming systems in Malawi. This study necessitates the use of a combination of biophysical and economic procedures when evaluating promising lines prior to variety release in order to identify the high yielding variety that will continuously bring sustained profits to the farmers amidst climate change.

Key words: *Climate risks, Target MOTAD, DSSAT, smallholder farmers, resource allocation.*

INTRODUCTION

Risks and uncertainties, their effects and how farmers react to those risks are major perils to smallholder agricultural production in Malawi where farmers lack information and capacity to predict future weather outcomes (Getnet *et al*., 2015). In this paper, risk is viewed as uncertainty embedded in the probable outcomes in maize production. Maize farmers are exposed to several risks, namely, price,

market, climate, biological and financial risks (Akhtar *et al*., 2019). Despite variability in temperature and rainfall, climate risk arises from extreme weather events like drought (or dry spell). In this paper, drought is defined as a natural feature, usually allied with warm and dry weather over an extended period of time (dry spells) causing less than normal water available on the land surface (Masih *et al*., 2014) required for maize growth. As an agro-based economy, scarcity of climate related data in Malawi makes agricultural productivity to be very unstable for rural smallholder farms.

Analysis of climate risk is very important in agriculture because climatic risks influence smallholder farmers' decisions to allocate resources to agricultural production (Masih *et al*., 2014). However, in Malawi, limited research has been conducted that links climate related risks to agricultural resource allocation decisions in smallholder maize farming systems. Understanding the decision-making process of smallholder farmers under climate risk is critical for the development of novel strategies like climate-smart agriculture (CSA) for improving farm outputs. CSA is embedded in sustainable agriculture and rural development which, if reached, would contribute towards achieving the Sustainable Development Goals (SDGs) of lowering hunger, and improving management of the environment. Drought tolerant maize (DTM) is one example of technologies promoted under CSA (Lipper *et al*., 2014). Sub-Saharan African (SSA) countries like Malawi, have progressed considerably in the use of improved maize varieties like DTM (Lipper *et al*., 2014). DTM is a focal point of this study since it is promoted under CSA in Malawi due to the importance of maize as a major food crop in many Malawian households.

Experimental research has studied the impacts of climatic risks on an array of major crops. The experimental models are used because they provide a systematic means to map variations in climatic and other environmental inputs (Ngwira *et al*., 2014). Yet, they are nearly not capable of capturing the linkage between climate related risks and farmer resource allocation as they implement adaptation practices (Karali *et al*., 2013). This study enhances understanding of intricate relationship between economic and ecological aspects at farm level through coalescing information from both biophysical models (like DSSAT) and mathematical programming (MP). The objectives of the paper are (1) to evaluate the ability of DSSAT to predict and collate DTM and non-DTM yields under climatic risk and (2) to use a bio-economic procedure developed using DSSAT and Target-MOTAD to explore how climatic risk influence allocation of resources to DTM and non-DTM production in the sampled region

MATERIALS AND METHODS

Study Site

The study used a farm from Chitedze Research Station in Lilongwe due to the availability of observed DTM and non-DTM maize data and daily rainfall and temperature data required for the analysis.

Decision Support System for Agro-Technology Transfer (DSSAT) Cropping Systems Model (CSM)

The CSM-CERES-Maize module (Jones and Kiniry, 1986) was used and is based on the effects of weather, soil characteristics and crop management practices. The drought tolerant SC 403 and non-drought tolerant MH 18 from the sampled experimental field were used. To evaluate the biophysical model, the CERES-Maize model requires six genetic coefficients that govern the life cycle and reproductive growth of maize varieties as provided in Table 1 for the varieties.

Table 1. Calibrated genetic plant growth coefficients of maize varieties used in CERES-Maize model for SC403 (DTM) and MH 18 (Non-DTM)

Coefficient	**Description**	**SC 403**	**MH 18**
P1	Thermal time (degree days above the base temperature of 8^{o}c) from seedling emergence to the end of juvenile stage.	235.0	245.0
P2	Photoperiod sensitivity associated with delayed growth under unfavourable long day length condition (no unit)	0.27	0.28
P5	Thermal time from silking to physiological maturity (degree days above the base temperature of 8^{o}c in the maturity stage)	800.0	843.0
G2	Potential maximum number of kernels per plant	630.0	417.3
G3	Kernel filling rate under optimum condition (mgd-1)	7.0	7.87
PHINT	Interval in thermal time between successive leaf appearance (degree days above a base temperature of 8^{o}c)	38.90	75.0

*Source: Ngwira *et al*., 2014; Tesfaye *et al*., 2015

Statistical Analysis

The Root Mean Square Error (RMSE) and mean percent difference (MPD – obtained as the mean of %D) were used to evaluate the performance of DSSAT (Ngwira 2014).

$$RMSE = \left[\left(n^{-1}\sum(Yield_{simulated} - Yield\ _{observed})\right)^{2}\right]^{0.5}$$

$$\%D = \left[\frac{Yield_{observed} - Yield_{simulated}}{Yield_{observed}}\right] x100$$

The RMSE value of zero indicated the goodness of fit between simulated and observed data. High values of D that are close to 1 indicate good model performance and better relation of observed versus simulated yields.

Target MOTAD Model to Determine the Optimal Production of Maize

The Target MOTAD was used to determine optimal resource allocation in the production of maize. Type of maize has been specified according to drought or non-drought tolerance. The main activities in the Target-MOTAD model include maize production related with three states of nature, seasonal labour used, maize crop sales and capital used in maize production. The model defines several constraints that are faced by a maize farmer such as limited amount of land and labour use, limited cash for input purchase using the available resources at farm household and the states of nature related to climate risk. The model was run in the General Algebraic Modelling System (GAMS) software (Version 25.0.2). Table 2 presents the three states of nature related to climate risk from Chitedze research station. The results indicate that both rainfall distribution and rainfall amount are average in the study area for about 75% of the times. Furthermore, about 12.5% of the times, rainfall distribution was bad while rainfall amount was average and for the other 12.5% of the times rainfall distribution was average whilst amount of rain was poor. The data used to compute the probabilities in Table 2. relates to daily rainfall data collected between 2006 and 2016 at Chitedze Research Station.

Table 2. States of nature linked to weather risk at Chitedze Research Station

	Rainfall amount		
Rainfall distribution	Poor (413.6<R*<620.5)	Average (620.5<R*<1034.1)	Good (R>1034.1)
Bad (SD*>121.7)	Not applicable	0.1	Not applicable
Average (73<SD*<121.7)	0.1	0.8	Not applicable
Good (SD*<73)	Not applicable	Not applicable	Not applicable

Key: SD* = standard deviation for rainfall amount; R* = Rainfall amount (mm).
*Source: Chitedze Research Station Meteorological Service Department (2017)

The Objective Function

The Target MOTAD model followed Tauer (1983) and was set as follows.

$$Max\ (Z) = \sum_{d=1}^{3}\sum_{j=1}^{2}\left[E\left(\bar{C}_{dj}\right)\left(x_{dj}\right)\right]$$

Where; $\left[E\left(\bar{C}_{dj}\right)\left(x_{dj}\right)\right]$ is the expected gross margin in MK for maize category j in rainfall state of nature d grown under the rain-fed condition, $\bar{C}_{dj}$ is the gross margin per ha, x_{dj} is the crop acreage, d is the 3 rainfall states of nature namely; good, average and poor as classified from the rainfall monthly data from 2006 to 2016 and $j = 1,2$ is DTM and non-DTM maize categories whose yields were simulated from the DSSAT crop model

Constraints

Labour Constraint

The amount of labour required per hectare to produce maize crop type j in rainfall state of nature d under rain-fed conditions is specified as

$$\sum_{d=1}^{3}\sum_{j=1}^{2} l_{dj}x_{dj} \leq W_d \ (j = 1,2)$$

Where; W_d is the amount of labour in man-days that is available in rainfall state of nature d, l_{dj} is the amount of labour in labour hours required to produce one hectare of DTM and non-DTM maize crop type (j) under rain-fed conditions, x_{dj} is the amount of land allocated to activity j measured in hectares

Land constraint

The specification of the land constraint is as follows:

$$\sum_{d=1}^{3}\sum_{j=1}^{2} h_{dj}x_{dj} \leq L_d \ (j = 1,2)$$

L_d is all the land available for cropping while h_{dj} is all the land area required to produce per hectare of maize crop type j in rainfall state of nature d

Capital constraint

$$\sum_{d=1}^{3}\sum_{j=1}^{2} r_{dj}xd_j \leq R_d \ (j = 1,2)$$

This constraint represents (r_{dj}) the amount of cash capital measured in Malawi Kwacha deflated by year 2012 which is the base year required to produce per hectare of maize crop type j and R_d is the amount of cash capital available at the start of the cropping season in rainfall state of nature d.

Maize self-sufficiency constraint

Estimation of the maize self-sufficiency constraint was based on the annual maize requirement of each member of the household according to their ages.

$$\sum_{d=1}^{3}\sum_{j=1}^{2} f_{idj}xd_j \geq F_d \ (i = 1,2)$$

Where; f_{dj} is the yield of maize produced per hectare of maize crop type j in kg/ha while F_d is the annual amount of maize required for the household in kg in rainfall state of nature d

Negative deviation from a pre-specified target revenue constraint

This constraint is presented as:

$$\sum_{d=1}^{3}\sum_{j=1}^{2} c_{dj}xd_j + Y_k \geq T \ \ for\ all\ k$$

Where; Y_k are the deviations below target income during rainy season for the k^{th} state of nature. T represents target income during the rainy season. The states of

nature are defined as a particular set of probabilities representing years of good, average, and poor rains during the year of crop simulations.

Sum of negative deviations multiplied by the probabilities of the states of nature constraint

Tauer (1983) considered that during the planning period of a decision maker, perception of risks entails that the total deviations have to be confined to a specific value. Hence, to define this aspect of risk perception, he equated the sum of the product of probabilities of each states of nature and the deviation associated with the appropriate state of nature as specified below;

$$\sum_{k=1}^{3} p_k y_k \leq \lambda$$

Where; K is the number of states of nature, $\boldsymbol{p_k}$ is the probability of the kth state of nature; and $\boldsymbol{\lambda}$, a risk parameter represents the sum of expected negative deviations below the target income in MK.

RESULTS AND DISCUSSION

Evaluation of Simulated DTM and non-DTM

The evaluated CERES-Maize model verified a good agreement between observed and simulated grain yield data (Table 3). The model methodically simulated maize grain yield for all treatments with differences ranging from -5.3 to 9.6%, 2.8 - 10%, -2.1 to -16.7%, 4.6 - 5.2% and 4.6 - 5.2% for 2006 –2007, 2007–2008, 2008-2009, 2011-2012 and 2014 – 2015 growing seasons respectively. Overall, the RMSE were found to be 758.3 kg ha^{-1} 394.2 kg ha^{-1} 458.9 kg ha^{-1} 402.2 kg ha^{-1} and 570.0 kg ha^{-1} for 2006–2007, 2007–2008, 2008–2009, 2011-2012 and 2014–2015 growing seasons, respectively as shown in (Table 6.1). Similarly, MPD were found to be as 4.7 %, 6.4%, 2.4%, 8.5% and 0.1% for 2006–2007, 2007–2008, 2008–2009, 2011-2012 and 2014–2015 growing seasons, respectively. This comparison shows that the model has the potential to simulate maize yield for an independent data set of the given years. Therefore, performance of CERES-Maize model was acceptable under a given set of conditions. As such, the model was used for further decision-making on maize variety choices.

Prediction of Maize Grain Yield

Predicting maize grain yield necessitates developing and fine-tuning the promoted maize varieties in Malawi (Ngwira *et al*. 2014). Results in Table (4) divulge significant differences ($P< 0.01 – p<0.05$) between DTM and non-DTM yields from years 2006 to 2007 and 2011 to 2015. Mean maize yields for DTM were more than non-DTM from 2006 to 2014. The differences were much higher (>20% ha^{-1}) in years 2006, 2007 and 2014 by 22.19% ha^{-1}, 27.80% ha^{-1} and 24.34% ha^{-1} respectively. These findings concur with the findings of Tesfaye *et al*. (2018) who reported more yields for DTM compared to other maize varieties that lacks heat tolerance genes.

Table 4. Simulated maize grain yield (kg) for DTM and Non-DTM, Chitedze Research Station

Maize Type	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
DTM	5382	5904	4309	4339	4264.6	4790	5021	5238	5052	4134
Non-DTM	4188	4263	4280	4217	4034.0	4023	4582	4230	3822	4333
P-value	0.000	0.000	0.919	0.704	0.490	0.002	0.041	0.004	0.000	0.000

Target-MOTAD Analysis Simulated DTM and non-DTM under Alternative Rainfall Scenarios

Risky Neutral Situation

Under the risk neutral case, the higher marginal value of MK551,500.00 imply that the resource has a bigger marginal effect on the objective function. Likewise, the slack of MK40, 000 and 68.28 labour hours is clear evidence that not all capital and labour were used respectively. The maize sufficiency requirement had no effect on the objective function due to its zero marginal value.

Table 5. Optimal resource levels from the risk neutral case

Resource	Value	Used	Unused	Marginal value (MK)
Land (ha)	2.1	2.10	0.0	551,500.00
Capital (MK)	250.000.00	210,000.00	40,000	0.0
Labour (man hours)	1400	1331.72	68.28	0.0
Maize sufficiency requirement (kg)	**Maize produced**	**Marginal value (MK)**		
Bad-average	3,000	0.0		
Poor-average	3,000	0.0		
Average-average	3,000	0.0		

Risky Situation

Risk was introduced in the optimization problem as the negative deviation from mean income following Watts *et al*., (1984) by varying target income to assess the negative deviations from the mean (risk levels) to achieve the third objective and to test the third hypothesis. The target income used for this analysis has been calculated as the annual income needed to cover fixed costs. These include those variable costs not already accounted for in the calculation of net returns i.e. the cost of basic food commodities e.g. salt, sugar, relish etc. A set of 10 efficient farm plans (Table 6) was obtained by parameterising the level of risk (deviations from

mean income) from MK 48,706.20 average deviation to MK5,411.77 (Table 6). These farm plans maximise expected income for a given risk level, subject to minimised negative deviations from the target income. The variations in risk and optimal solutions are obtained until all feasible possible changes occur, and the value of expected income cannot be improved by increasing the level of risk. The Target MOTAD solutions (Table 6) indicate that at higher target income levels, the risk is also high. Furthermore, land was constantly allocated to DTM at all risk levels and they attracted the same mean income despite the state on nature. The results imply that with the target income met, farmers have optimally achieved the 3000kg annual food requirement, thus achieving their household food security. These results lead to a conclusion that farmers must allocate all their resources (land, capital, and labour) to DTM when risk increases regardless of the state of nature. These findings concur with the findings of Tesfaye *et al*. (2018) who reported more yields for DTM compared to other maize varieties that lacks heat tolerance genes.

Table 6. Trade-offs between risk (negative deviations from target income) and mean income, with associated enterprise combinations-Target-MOTAD Model

Farm Plan	**Mean Income (MK)**	**Target income (MK)**	**∑ Negative Deviations (⅄) from mean Income**	**Enterprise Mix (ha)**	
				DTM	**Non-DTM**
1	1,158,142.01	1,028,242.00	48,706.20	2.10	0.00
2	1,158,142.01	974,124.00	43,294.40	2.10	0.00
3	1,158,142.01	920,006.00	37,882.60	2.10	0.00
4	1,158,142.01	865,888.00	32,470.80	2.10	0.00
5	1,158,142.01	811,770.00	27,059.00	2.10	0.00
6	1,158,142.01	757,652.00	21,647.20	2.10	0.00
7	1,158,142.01	703,534.00	16,235.40	2.10	0.00
8	1,158,142.01	649,416.00	10,823.60	2.10	0.00
9	1,158,142.01	595,298.00	5,411.77	2.10	0.00
10	1,158,142.01	541,180.00	0.03	2.10	0.00

Note: ⅄ is the maximum allowable income deviation from the target (the risk aversion coefficient)

Figure 1 below shows the Target-MOTAD risk income frontier at all levels of target income. According to the figure, higher levels of expected incomes are associated with higher negative deviations (risks). This means, along the graph, a maize farmer will maximize profits despite higher levels of risks. This implies that regardless of which state of nature, farmers who grow DTM are expected to get higher profits which will be even higher at higher risk levels.

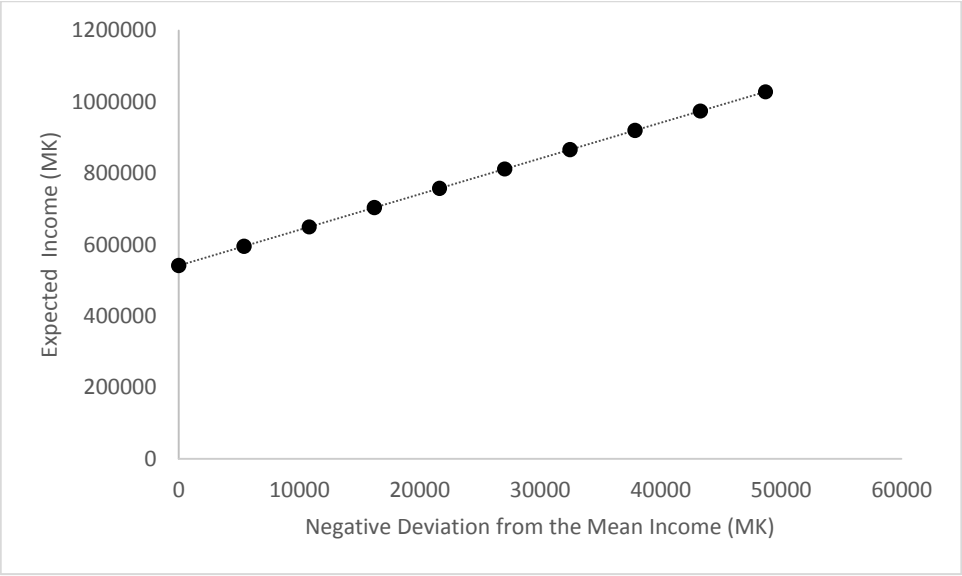

Figure 1. Efficient set of expected income and negative deviation from mean income on a maize farm

CONCLUSION

The validation of DSSAT model was successful since it was able to simulate the maize yields adequately thus mimicking what is happening on the ground. The study has further shown that adoption of DTM in climate risk prone areas might prepare smallholder farmers for the coming future threats of climate variability during bad years to improve food security situations in their areas. From the simulated maize yields for DTM and non-DTM, the performance of maize was largely affected by climate since the agronomic practices were followed as required. Finally, the use a bio-economic procedure developed using DSSAT and Target-MOTAD has exhibited a methodological contribution to the growing body of academic literature on climate variability and agricultural economics. For instance, while few economic models explicitly consider risk in the objective functions, they slackly assume normal distribution of climatic variables such as rainfall and temperature. Using the case of Chitedze research, the Target-MOTAD model incorporates farmers risk attitude and rainfall distribution to assess farmer's resource allocation decisions in response to climate variability by considering three important issues; the farmers risk attitude, the use of simulated maize yields from DSSAT plus incorporation of three states on nature that captured rainfall distribution and amounts.

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HOW DO ADAPTATION OPTIONS TO CLIMATE CHANGE, RISK PREFERENCES AND SOCIAL CAPITAL AFFECT TECHNICAL EFFICIENCY OF SMALL VINEYARD FARMERS IN CENTRAL CHILE?

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ABSTRACT

Climate change can be seen as a shock that decreases the value of economic activities and production functions. Therefore, this study estimates technical efficiency as an integrated approach with risk preferences and social capital for small vineyard farmers who have adapted to climate change, because empirical evidence shows the key role of adaptation, risk preferences and social capital related to technical efficiency on a one-to-one basis, but not as overarching analysis. This study took place in the O'Higgins and Maule regions of central Chile, data were collected through a field experiment and an exit survey from September to December 2016. Specifically, we conducted an artefactual field experiment to elicit risk preferences from 175 small vineyard farmers; we used the midpoint method to estimate the Cumulative Prospect Theory (CPT) parameters, which indicate vineyard farmers are risk averse, sensitive to losses, and tend to distort probabilities. Then we applied a stochastic frontier analysis on the main variety area of vineyards. Results showed that the influence of capital (0.55) and number of vines (0.32) is higher enough; whereas, labor (0.13) and intermediate inputs (0.11) are also important but relatively low. The scale elasticity is 1.11, showing a Constant Returns to Scale (CRS). On average, technical efficiency was 0.73, which means that farmers could improve their performance by 27%. Additionally, results suggest that experience and education positively influence the technical efficiency, contrary to age, gender, region and density; whereas, access to extension services and irrigation increases efficiency. Also, general trust and membership in farmer organizations increases efficiency; and, as we expected, risk aversion and probability weighting decreases efficiency. In this regard, it is necessary to design policies and strategies focused on facilitate accessibility to exchangeable inputs; in the promotion of extension services with greater action area; facilitate access to irrigation through subsidies and credits; improve trust in

programs and networks; develop cooperative enterprises or local and horizontal organizations to share information and services from farmer to farmer; and also generate action plans to promote a better risk and loss behavior in order to seize technological and economic opportunities and not overestimate extreme events.

Keywords: *Technical Efficiency, Stochastic Frontier Analysis, Cumulative Prospect Theory, Risk preferences, Social Capital, Adaptation to Climate Change, and Vineyard farmers.*

INTRODUCTION

Climate change is an alteration of weather conditions over a period of time, normally more than two decades, and has a negative or positive effect on human societies or natural ecosystems. In the case of negative effects, changes in weather patterns (e.g., as a result of changes in temperature or rainfall) can stimulate an increase of pests and disease pressure, droughts or flooding, among other events that could lead to damage on infrastructure and production systems. Climate change means an immediate technological shock that decreases the value of economic activities over time (Kelly et al., 2005); and indeed, climate change can affect the deterministic and stochastic parts of a production function (Alpizar et al., 2011; Kelly et al., 2005). Thus, one process to face climate change effects is adaptation. Several studies point out that implementing relevant adaptation options increases productivity or technical efficiency of crops by reducing negative effects from climate change (Wossen et al., 2015; Roco et al., 2017; Khanal et al., 2018). Accordingly, it is necessary to integrate the effect of adaptation options into technical efficiency analysis. Also, to improve the analysis of technical efficiency in the face of climate change, it is important to include farmers´ risk preferences.

We contribute to the literature in three key aspects: 1) we apply Cumulative Prospect Theory determining risk aversion, loss aversion, and the probability weighting function to understand their effect in technical efficiency; 2) we extend the analysis of the role of social capital by including trust and social norms in addition to social network; 3) we incorporate in the analysis the effect of anticipatory and reactive adaptation options. This study was implemented in the O'Higgins and Maule regions of central Chile, home to 80% of the total grape production in the country, where around 60% of the farmers are small. We conducted an artefactual field experiment to elicit risk preferences from 175 small vineyard farmers. We used the midpoint method to estimate the risk preference parameters. We apply a stochastic frontier analysis on the main variety of grape produced in the vineyard, which allows us the opportunity of appraisal of individual farmer capacities in comparison to a frontier.

MATERIALS AND METHODS

Area of study

This research took place in the two most important regions for the cultivation of vineyards in Chile: Region VI of O´Higgins and Region VII of Maule. For

instance, Region VI of O'Higgins contains 34.44% (47,382.07 ha) of the total area in Chile under grape cultivation, while Region VII of Maule contains 38.88% (53,496.51 ha).

Data

Sample data

In general, the data for this study were collected through a field experiment and an exit survey with vineyard farmers of central Chile. We selected farmers based on a database from the University of Talca, Chile. This original database was collected from November 2014 through February 2015 and consisted of 452 vineyard farmers from the Region VI of O'Higgins and Region VII of Maule and it is a cross-sectional data with socioeconomic, irrigation systems, production and social capital variables.

From this database, we randomly selected 204 small vineyard farmers from the regions mentioned above because of their importance for vineyard cultivation. Afterwards, we contacted these farmers by phone to find out their willingness to participate in the research. From these 204 vineyard farmers, 22 were excluded because they no longer cultivate vineyards, and another 7 also were excluded because we identified inconsistencies in the data. In the end, the sample size for this study was 175 small vineyard farmers distributed throughout the regions of O'Higgins and Maule in a total of 16 communities.

Stochastic frontier specification and variable selection

Small vineyard farmers from Region VI of O´Higgins and Region VII of Maule (central Chile) show different proportions of area allocated to vines, a large range of vine varieties, different technologies, management, and market orientation, which means different scales of the vineyards' production. In this regard, the stochastic frontier analysis (SFA) allows us the opportunity of appraisal of individual farmer capacities in comparison to a frontier (Meeusen and van Den Broeck 1977), where deviations from the frontier are explained by the composed error term: the statistical error term or random noise (v_i) distributed as N (0; σ^2_v), and the inefficiency error term (u_i) distributed as N^+ (0; σ^2_u) (Aigner et al., 1977), as we explained in section 2 of the theoretical framework. Nevertheless, as we used a production function based on cross sectional data where farms vary in size, among other factors, we can expect that the inefficiency error term (u_i) is heteroscedastic (Caudill and Ford 1993; Caudill et al., 1995: Wang and Schmidt 2002) and can be dependent on a group of covariates (Wang and Schmidt 2002). Basically, we considered the effect of a vector of variables on the variance of the inefficiency error term distribution, as we can see in equation (15) N^+ (0; σ^2_u) where $\sigma_u = \exp(\mathbf{z}\delta)$, this condition is called the scaling property and explains if the models adjust to the data (Simar et al., 1994; Caudill et al., 1995: Wang and Schmidt 2002). However, not all models have this condition. For instance, authors such as Kumbhakar et al. (1991), Huang and Liu (1994), and Battese and Coelli (1995) take into account the effect of a vector of variables on the mean of the

inefficiency error term distribution, in this case, N^{+} (μ; σ^2_u), where μ= f(zδ); thus, a higher μ means a higher inefficiency.

In this research, we applied the model developed by Wang and Schmidt (2002) taking into account the scaling property, because, as we mentioned before, due to the differences in area for vines, vine varieties, technologies, management, and market orientation, we anticipated variation at the efficiency level. We were sure about this model after the procedure of estimation and analysis of technical efficiency because we identified the effects of covariates in the model. For the production frontier, we have chosen the Cobb-Douglas function form and tested it against the more flexible translog form. The likelihood Ratio Test (LRT) confirms the selection of the Cobb-Douglas form at a 1% significance level. We also performed the LRT for the selection of the input variables, to avoid omitted or overestimated variable bias.

The Cobb-Douglas production function as an empirical model has an easy interpretation and also assumes equal production elasticities, scale elasticities and unitary elasticities of substitution for firms (Coelli and Sanders, 2013; Greene, 2008), and in general, the coefficients can be interpreted as output elasticities. Fundamentally, the general model is:

$$\ln y_i = \beta_0 + \beta_1 lnK_i + \beta_2 lnL_i + \beta_3 lnIM_i + \beta_4 lnNV_i + \beta_5 PA_i + (v_i - u_i) \quad (1)$$

$$v \approx N(0, \sigma_u^2)$$

$$u \approx N^{+}(0, \sigma_u^2) \quad \sigma_u = \exp(z\delta)$$

Where the output (y_i) is the value of the total production of grapes in tons per main variety area, the inputs are capital stock (k_i) explained by the value of vineyards in the main variety area plus one-time investments such as irrigation and training system and labor (L_i) is the total labor days per year to apply agrochemical (fertilizer, acaricide, herbicide, insecticide, and fungicide) and carry out management activities (pruning, harvesting, disbudding, and toping). Intermediate inputs (IM_i) is defined as the total value or cost of agrochemicals (fertilizer, acaricide, herbicide, insecticide, and fungicide) and water rights, the number of vines (NV_i) per area of the main variety, and the plantation age (PA_i). In addition, we included variables that might shift the production frontier: a dummy variable for variety quality (low or high), and training system (parrón or espaldera). All these variables were selected in order to generate a constant flow of services across the farmers, and also to avoid multicollinearity. Furthermore, these variables were scaled by their mean and then we took logarithms in order to have a better convergence of the function. Then, we analyzed the determinants of technical efficiency to explain deviations from the frontier accordingly to Wang and Schmidt (2002) and the scaling function defined as: (z_i,) = exp (z'):

$$\begin{aligned} h(z_i, \delta) = \exp(&\delta_1 + \delta_2 Ex_i + \delta_3 Ag_i + \delta_4 Ed_i + \delta_5 Ge_i + \delta_6 Ti_i + \delta_7 Re_i + \delta_8 De_i \\ &+ \delta_9 Ad_i + \delta_{10} Ir_i + \delta_{11} Pp_i + \delta_{12} Pd_i + \delta_{13} Ma_i + \delta_{14} Hs_i \\ &+ \delta_{15} Md_i + \delta_{16} In_i + \delta_{17} Tr_i + \delta_{18} Nt_i + \delta_{19} Nr_i + \delta_{20} M_i \\ &+ \delta_{21} Ra_i + \delta_{22} La_i + \delta_{23} Pw_i) \end{aligned} \quad (2)$$

Where Ex_i is experience in vineyards (years), Ag_i is age of farmers (years), Ed_i is level of education (years), Ge_i is gender (male), Ti_i is distance to market (minutes), De_i is density (number of vines per ha), Ad_i is advisor, Ir_i is type of irrigation (drip or furrow), Pp_i is prevention of pests through pheromone diffusers (yes or no), Pd_i is prevention of diseases (yes or no), Ma_i is management (conservation practices), Hs_i is mitigation of frost (heating systems), Md_i is mitigation of diseases (chemical), In_i is insurance (yes or no), Tr_i is general trust (yes or no), Nt_i is network (number of farmers who adopted technologies), Nr_i is norm of reciprocity (organization of agricultural events to improve knowledge), M_i is membership in agricultural organizations (yes or no), Ra_i is risk aversion, La_i is loss aversion, and Pw_i is probability weighting (distortion or not of probabilities). Finally, we use Battese and Coelli (1988) for the estimation of technical efficiency (*TEi*) of each farmer, as it shows in Kumbhakar and Lovell (2000):

$$TE_i = E\left[e^{-u_i} | \varepsilon_i\right] \quad (3)$$

RESULTS AND DISCUSSION

Risk preferences parameters

From the total farmers of the sample (175), we estimate the Cumulative Prospective Theory (CPT) risk preferences parameters (σ, λ and γ) (Table 1). Our estimations are consistent with estimations in the literature (see section 2.2). For instance, σ =0.84 which indicates risk aversion among the farmers. Regarding loss aversion, λ =2.98, we can assume that vineyard farmers are three times more sensitive to losses than to gains. Finally, the value of probability weighting is γ=0.75 which means that vineyard farmers tend to overestimate small probabilities.

Table 1. Risk preference parameters using the midpoint method (inequalities).

Parameter	**Value**	**Std. Err.**	**β_0= 1**
Curvature of value function (Risk aversion) (σ)	0.84***	0.034	0.000
Loss Aversion (λ)	2.98***	0.286	0.000
Probability weighting (γ)	0.75***	0.013	0.000
Observations	175		
Clusters	0		

Source: own calculation.

Note: *p < 0.1, ** p < 0.05, *** p < 0.01.

To estimate the parameters of risk aversion, probability weighting and loss aversion for each observation (each individual farmer), we follow the midpoint method established by Tanaka et al., (2010) and applied by Liu (2013); Bocquého et al., (2014); and Ward and Singh (2015).

Functional form: parameters of the production function and determinants

As we stated before, this research took place in Region VI of O´Higgins and Region VII of Maule, central Chile. In these regions, the vineyard production is well explained by a Cobb –Douglas Stochastic Frontier production function, we

choose this functional form after testing it against the translog production function. In general, we performed the Likelihood Ratio Test (LRT) to confirm our selection at a 1% significance level (p-value=0.055). This is consistent with the literature, for example, Moreira et al (2011) analyzed the technical efficiency of Chilean grape farmers in central Chile through a Cobb –Douglas production function. In our production model, capital, number of vines per main variety, labor and intermediate inputs are the most important inputs. The coefficients of this group of inputs are all significant, positive and were estimated through the Maximum Likelihood (ML) approach. Other studies in grape vine production indicate that the most influential inputs are block size (an area with one variety and a certain management), labor and machinery (Moreira et al., 2011), and also that land, labor, and agrochemicals (pesticide, herbicide and fertilizer) are the most imperative inputs (Piesse et al., 2018). To a certain extent, these results are similar, as we included the land value in capital and we used number of vines per main variety instead of area in order to avoid multicollinearity among the variables. In addition, our model includes intermediate inputs such as agrochemicals (pesticide, herbicide and fertilizer), but including water rights.

According to the literature, the influence of capital (0.55) and number of vines (0.32) is high enough, whereas, labor (0.13) and intermediate inputs (0.11) are also important but relatively low (Table 2). Finally, the sum of these exchangeable inputs or the scale elasticity is 1.11, showing a Constant Returns to Scale (CRS), we confirm this condition by the Wald-test (p=0.8507). This Constant Returns to Scale (CRS) means that output increases by the same proportional change as all inputs change. Regarding the variables that might shift the production frontier, age of vines is negative, as we expected, but not significant. Whereas, variety quality is negative and significant, which makes sense because generally, the higher the quality the less production. The training system ("parrón") is positive and significant, which means this trellising system helps to improve production.

Table 2. Estimated coefficients for the stochastic production frontier.

Parameter	**Value**	**Std. Err.**
Intercept	0.29***	0.091
Capital	0.55***	0.164
Labor	0.13**	0.073
Intermediate inputs	0.11**	0.058
Number of vines	0.32***	0.087
Age of vines	-0.004	0.002
Variety quality	-0.44***	0.104
Training system	0.50***	0.133
Observations	175	
Chi2	441.41	
P	0.0000	

Source: own calculation.

Note: *p < 0.1, ** p < 0.05, *** p < 0.01.

The mean Technical Efficiency index is 0.73 (73%) with a standard deviation of 0.17, which indicates that farms could improve their performance by 27%.

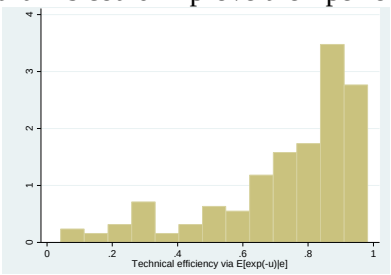

Figure 1. Technical efficiency of vineyard farmers in central Chile.
Source: own calculation.

Deviations from the frontier could be explained by socioeconomic, technological, social capital and behavioral determinants, as we can see in Table 3. As we mentioned in the theoretical framework and methodology, the inefficiency model has a half-normal distribution. In general terms, it is possible to see and understand the effect of socioeconomic variables, adaptation options, social capital forms and risk preference parameters in technical efficiency of small vineyard farmers of central Chile.

Table 3. Determinants of technical efficiency.

Variable	**Coefficient**	**Std. Err.**	**Effect on TE**	**ME**
Experience	-0.04***	0.015	+	-0.004
Age	0.04**	0.020	-	0.002
Education	-0.08	0.057	+	-0.544
Gender	1.91**	0.812	-	0.015
Time to market	0.02	0.019	-	0.004
Region	2.01***	0.752	-	0.013
Density	0.001***	0.001	-	0.002
Advisor	-1.27**	0.560	+	-0.001
Irrigation	-0.99**	0.530	+	-0.003
Prevention of pests (pheromone diffuser)	-0.06	0.662	+	0.004
Prevention of diseases	-0.98	0.808	+	0.015
Management	1.90***	0.664	-	0.016
Mitigation of frost	-0.67	0.513	+	-0.007
Mitigation of diseases	-0.10	0.468	+	0.015
Weather insurance	-0.58	0.765	+	0.005
General trust	-0.60**	0.254	+	-0.003
Network with adaptation	0.43	0.568	-	0.005

Norm of reciprocity (events)	0.34*	0.198	-	0.046
Membership	-0.90*	0.533	+	-0.002
Risk aversion	0.76**	0.454	-	0.003
Loss aversion	0.25	0.413	-	0.003
Probability weighting	2.88*	1.628	-	0.019
Observations	175			
Chi2	441.41			
P	0.0000			

Source: own calculation.
Note: *p < 0.1, ** p < 0.05, *** p < 0.01.

As we expected, experience in vineyard production has a positive effect on technical efficiency (-0.04) at a significance level of 1%, because more experience can lead to better decision making when farmers face production problems. In the case of age, this determinant decreases efficiency (0.04) and is significant at a 5% level, which is, in some cases, an expected result because we can assume that old farmers are not interested in change or improving their production system. On the contrary, young farmers could show more willingness to participate in extension services programs, adopt new technologies, improve or make changes to their systems in order to have better revenues, etc. Gender (=1 if male) also has a negative effect (1.34) on efficiency at a significance level of 5%, this could be interpreted as female farmers being generally better decision-makers. The distance to the closest market in minutes also has a negative effect on technical efficiency (0.02), this could be interpreted as: the farther from the market the less efficient, because more distance implies more logistics and costs to deliver the grapes, also those farmers that are further away from the market have less access to information and services (prices, technologies, extension services, credits, insurance, etc.). In the case of region, we identified that this variable decreases efficiency (2.01) with a significance level of 1%, which indicates that farmers from Region VII of Maule are less productive than farmers from Region VI of O´Higgins. To confirm this, we compared yields of each region. It turns out that farmers from Region VII of Maule has an average yield of 11.95 tons per ha, whereas farmers from Region VI of O´Higgins has an average yield of 15.37 tons per ha. This may be due to the proximity of Region VI of O´Higgins to the metropolitan region of the country, what means better access to markets, information and services. An interesting determinant is density (vines per ha) because this decreases efficiency (0.01) and is significant at a 1% level. Nevertheless, this could be interpreted as: the small vineyard farmers are more interested in high quality levels of grapevines which implies less vines per ha.

Regarding access to extension services, we identified that this has a positive effect on technical efficiency (-1.27) at a significance level of 5%, which could be interpreted as: the extension services from the government and ministries are well structured with enough quality to solve problems. In the case of irrigation (furrow),

this increases efficiency (-0.99) and is significant at a 5% level. This could lead us to believe that farmers do not have problems with water access, of course they paid for water rights but once they have access there are no problems with the amount, this could explain why so few adopt modern irrigation. Moreover, management decreases efficiency (1.90) at a significance level of 1%. This could be due an overuse of cultural practices such as pruning, disbudding, and topping. It would be interesting to analyze the effectiveness and costs of each activity. In relation to other technologies or adaptation options that help to face the negative effects of climate change (prevention of pests, prevention of diseases, mitigation of frost, mitigation of diseases), we found that these could have a positive effect on technical efficiency but they are not significant. Regarding social capital forms, as we mentioned before, empirical studies have showed that social capital plays a key role in understanding sources of inefficiency – efficiency (Binam et al 2004; Muange (2015)). Concretely, we found that general trust makes farmers more efficient or increases efficiency (-0.60) at a significance level of 1%: maybe farmers are more willing to cooperate or engage in productive interactions, they are able to learn from others and also from extension services. In general, more trusting farmers may be more open to receive and share information and services.

In the case of the norm of reciprocity, it has a negative effect on technical efficiency (0.34), this is significant at a 10% level. This result could be explained as such: more time invested in the organization of events to share knowledge could lead to having less time to make decisions about production or to be involved in key production activities on the farm, or perhaps the effect of these agricultural events is not as expected. Membership (-0.90) increases efficiency at a significance level of 1%, this could be explained by farmers being more exposed to information, services, shared experience and having access to technologies or adaptations options. Muange (2015) reports similar findings; he analyzed the effect of social network and membership as mechanisms to access finance, information, and other benefits. Binam et al., (2004) emphasize the role of social capital on technical efficiency; basically, they analyzed the relationship between membership and inefficiency, highlighting how social capital provides incentives for efficient production. They explained that member farmers of an association can share information about technologies and production activities, and they can increase their access to extension services. All of these effects improve market access and incomes.

Regarding risk preferences, in agriculture, risk plays an essential role for production decision making (Bocquého et al., 2014). Moreover, it has an important effect on decisions concerning inputs and also outputs (Kumbhakar 2002). However, thus far, risk preferences, estimated under cumulative prospect theory (CPT), have not been included in the combined analysis of technical efficiency, social capital and adaptation. For these reasons, we included the risk averse, loss averse and probability weighting variables in order to understand their effect on efficiency. In this case, we use these parameters as dummy variables because as Liu (2013) stated, these parameters show some grade of correlation that could lead

to a misinterpretation of the results. In this context, under cumulative prospect theory (CPT), farmers exhibit risk averse behavior (0.76), which is significant at a 5% level. Basically, this variable has a negative effect on technical efficiency, as risk averse farmers tend to avoid changes in technologies or practices, even more when these activities are expensive. Finally, the probability weighting variable (2.88) decreases efficiency at a significance level of 1%. This is because farmers who distort probabilities try to avoid changes in production systems.

CONCLUSIONS

This study estimates technical efficiency as an integrated approach including risk preferences and social capital for small vineyard farmers who have adapted to climate change. Empirical evidence shows the key role of adaptation options, risk preferences and social capital related to technical efficiency of productive systems on a one-to-one basis, however up to this point there has been no overarching analysis. This study focuses on Stochastic Frontier Analysis, in order to estimate technical efficiency and its determinants, which are: adaptation options to face climate shocks, risk preferences (risk aversion, loss aversion and probability weighting) and social capital forms (trust, network, and social norms). We also control for socioeconomics variables and physical characteristics of the farm. It is important to highlight that we estimate risk preference parameters under cumulative prospect theory (CPT) (curvature of the function as a measure of risk aversion, loss aversion and probability weighting) because to date, the majority of literature regarding the analysis of risk and technical efficiency has been based on expected utility theory (EUT), which cannot capture how farmers make decisions based on the possibility of gains or losses and how farmers distort probabilities. We used a Cobb – Douglas production function with a sample of 175 small vineyard farmers. Results showed that the influence of capital (0.55) and number of vines (0.32) is relatively high. Whereas, labor (0.13) and intermediate inputs (0.11) are also important but on a relatively low level. The scale elasticity is approximately 1.11, showing a Constant Returns to Scale (CRS), in other words, output increases by the same proportional change as all inputs change.

On average, technical efficiency was 0.73, which means that farmers could improve their performance by 27%. Results suggest that experience and education positively influence the technical efficiency of vineyard systems, as opposed to age, gender, region and density. Access to extension services and irrigation increases technical efficiency. Additionally, general trust and membership in farmer organizations increases technical efficiency. Finally, as we expected, risk aversion and probability weighting (distortion of objective probabilities) negatively influence the technical efficiency. In light of our findings, it is necessary to design policies that facilitate small farmers' access to a wide range of exchangeable inputs, in order to take advantage of the Constant Returns to Scale. In addition, it is necessary to promote strategies and policies with an emphasis on more extension services with greater action area, facilitating access to irrigation through subsidies and credits and improving trust in programs, projects, and networks. It is also

necessary to develop cooperative enterprises or local and horizontal organizations to share information and services from farmer to farmer and also to generate action plans to promote a better risk and loss behavior in order to seize technological and economic opportunities and not overestimate extreme events.

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IMPLEMENTING THE HIERARCHY-ANALYTIC PROCESS WITHIN FOREST FRUITS FROM MUREȘ COUNTY, ROMANIA

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ABSTRACT

Romanian forest ecosystems prove their true value through the complex diversity they offer. Varied relief forms, site conditions, temperate climate and the stand composition and structure elements sustain the apparition of vegetation layers and their population with diverse forest species that accentuate biodiversity. The economy from Romania's forest area is improved by the increased potential of harvesting a limited number of wood or non-wood products in order to ensure the population's needs and wellbeing. The activity of trading forest goods is encouraged by the maintenance of a good collaboration with international companies. The purpose of the present research is to analyse the most appreciated forest fruits from Mureș County, România. A total number of eight forest fruits were selected from the non-wood products category and were distributed in the following classes: achene (acorn, hazelnut), false fruits (rosehip), pluri-drupes (raspberry, wild strawberry), pseudo-beny (pulp cones from *Juniperus* L Genus.), drupes (*Prunus* Genus) and benyform drupes (black elder). The analytic hierarchy process was used in the evaluation of the qualitative and quantitative criteria. Based on it, eight alternatives were attributed to each analysed fruit using 19 evaluation criteria. The Expert Choice Desktop software was used in order to emphasize the performance efficiency. As such, the most valuable forest fruits from this area proved to be *Rosa canina*, *Rubus idaeus* and *Fragaria vesca*. In regard for the harvesting of non-wood products, managers from the forest sector must take into account analyses that can evaluate the offered economic potential, especially in particular cases.

Keywords*: analytic hierarchy process (AHP), Expert Choice Desktop, harvesting period, market, forest fruits.*

INTRODUCTION

In some rural locations of Finland, the harvesting of edible mushrooms is used as an activity of recreation, supplying some small markets or for home consumption, being also a good income for disadvantaged rural inhabitants (Cai *et al*., 2011).
In Africa, at the XIV World Forestry Congress in Durban, the forest resources were defined as multiple products which are indivisible in creating an evidence for

different investments in energy, lands or payments for environmental purposes (FAO, 2015). In some particular cases, some specific conglomerates from institutional structures have impacts in non-wood forest products innovations (Ludvig *et al.*, 2016). The variety of non wood forest products constituted from fruits (mushrooms, nuts etc), spices, herbs, medicinal plants or game were used for human wellbeing, assuring food, medicine and cultural or social demands for millennia, but today it is an evidence that these resources are underestimated because of the poorly information introduced in the international statistics (Sorrenti, 2017). For the advance of European bioeconomy, the non-wood forest products bring a specific attention in the public debate, being a part of changing something in their lifestyle. In some regions where the wood is not so demanded, non-wood forest products seems to bring a great potential in economies from rural populations, assuring viability and profitability in social and economic environment (Huber *et al*., 2019).

Romania owns besides wood raw material, a considerable quantity of non-wood forest products which are introduced and commercialized especially on the external market (Bragă and Dincă, 2019). Furthermore, Romania owns large areas with native species (maple, ash, sycamore, wild service tree) which are appreciated for its high quality of wood (Dincă and Dincă, 2019). The aim of the study is to emphasize the most important forest fruits from Mureș County and the examine the modalities which can improve the harvesting management.

The total surface of Mureș County is of 6.714 km² (figure 1) which represent 2,8% from the total surface of Romania. It is situated in the centre of Romania, the name coming from the river with the same name, Mureș, which cross the county from the northeast at southwest. This county is characterized by the hilly and hilly plateau relief in a proportion of 50% from surface and the other half includes the Transylvanian Subcarpathian hills and the presence of Călimani-Gurghiu volcanic mountains. In 2018, the total forest fund surface was of 220 thousand hectares, from which 213.6 thousand hectares represents the forest surface and 6.4 thousand hectares include another lands. In the same year, the land surface in which were executed artificial regenerations was about 295 hectares, from which 182 hectares were planted with seedlings of softwood species and 113 hectares using seedlings with hardwood species (https://mures.insse.ro/).

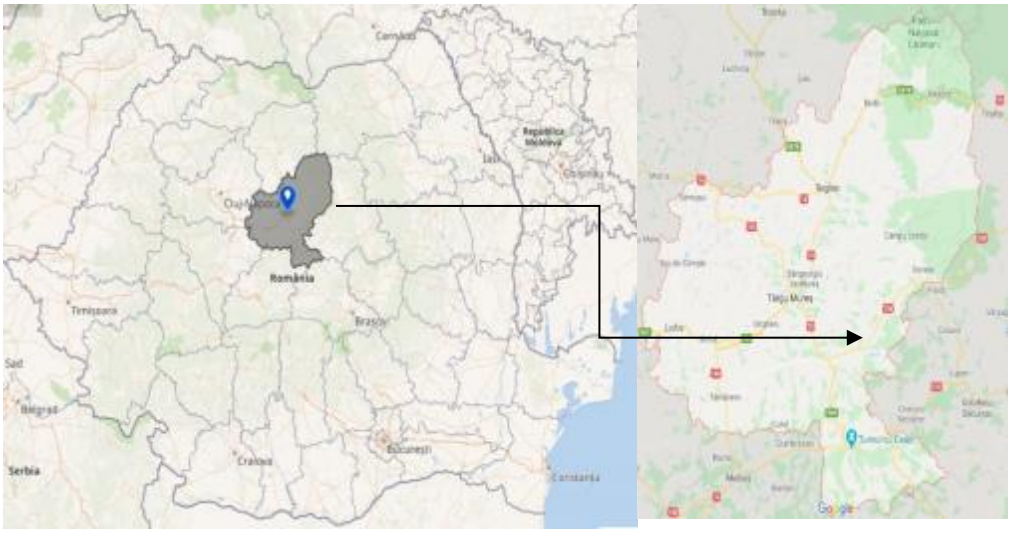

Figure 1. Study area Mureș County (source: www.wikipedia.org)

MATERIAL AND METHODS

The most widespread non-wood products, namely forest fruits were highlighted in some databases collected within the forest districts from this county, reports and documents of some projects implemented in the annual process of utilization. As methods, it was utilized the analytical hierarchy process (AHP), which was presented in COST 1203 action (European non-wood forest products network). This process bring an advanced analysis for evaluating the potential of forests fruits using 19 specific criteria and 8 types of alternatives promoted by the decision making process. The analytical hierarchy process was developed in 2008, by the expert Thomas Saaty, including the sequence of some "sub problems" that can be analyzed and resolved by independency (Saaty, 2008; Dincă *et al.*, 2020). The best decisions can be obtained by using this method, being a structured technique which has implications in psychology and mathematics. AHP model makes decision makers to find the solutions of the "sub problems" choosing one of the best decisions which suits their goal and understanding.

There are few steps for comprising the decision problem:

1) the decision problem must be decomposed into a hierarchy of more easily division of sub-problems;

2) evaluating the elements of hierarchy and comparing them to each other two (pairwise comparison) at a time;

3) converting all of these evaluations to numerical values that can be processed and compared over the full range of the problem;

4) calculating the numerical priorities for each decision alternative.

This analysis include the 19-well established multi-criteria (table 1) such as: I) harvesting period, II) harvested quantity/ worker/8 hours, III) harvesting cost, IV) knowledge for harvesting, V) tools needed for harvesting, VI) complexity of the harvesting process, VII) development of the harvesting process, VIII) knowledge

for recognition, IX) distribution range, X) biotic threats, XI) abiotic threats, XII) perishability, XIII) market potential, XIV) market demand, XV) "celebrity" of the product on market, XVI) the price of the raw product, XVII) the price of the derived product, XVIII) portfolio of derived products and XIX) Transport (harvesting->storage centre). Each criterion have been evaluated by using a scale formed by arabic numbers summarized in the interval of (1…8), which represent the intensity of importance attributed for alternatives, alternative number 1 having equal importance (two actions contribute in equal mode for the same objective) and alternative number 8 having very strong importance intensity. However, for estimating the sensivity of the forest fruits it was used the Expert Choice Desktop software bringing the results about the importance of these fruits.

This kind of analysis was implemented in other similar studies from different counties of Romania, such as: Dolj (Cântar *et* al., 2018), Bihor (Timiș-Gânsac *et al*., 2018), Gorj (Vechiu *et al.*, 2018), Arad (Pleșca *et* al., 2019), Bacau (Blaga et al., 2019), Dâmbovița (Bragă and Dincă, 2019), Vrancea (Tudor and Dincă, 2019), Satu-Mare (Tudor *et al*., 2019).

RESULTS AND DISCUSSION

Based on the AHP we founded that the most demanded forest fruits classified by the intensity of importance are in order: rosehips (*Rosa canina*), raspberries (*Rubus idaeus*), wild strawberries (*Fragaria vesca*), hazelnuts (*Corylus avellana*), acorns (*Quercus sp.*), pulp cones (*Juniperus sp.*), bird cherries (*Prunus padus*) and elder berries (*Sambucus nigra*). The analysis was approved by the votes of 3 specialists who evaluated the actual contribution of each fruit and the behavior manifested in harvesting management. A very strong intensity of importance (figure 2) it was obtained in the case of rosehips, which is related to the range of distribution, harvesting and transporting operations (criterion 1, 3, 7, 9, 19). Harvesting periods of fruits are very important to be acknowledged, because if is not done in the perfect moment, the value of the fruit cannot be evaluated at the maximum potential. What is important to know is that the harvesting operations of forest fruits must be executed is the right moment of maturation (Vasile *et al*., 2016). Rosehips are appreciated for their culinary and pharmaceutical properties, being rich in vitamins (*C-1%) (Șofletea and Curtu, 2007). Raspberries and wild strawberries bring good results in the market including all the criteria regarding on demand and potential market, the multitude of derived products, raspberries being considered the "Celebrity" of the product on market (criterion 13, 14, 15, 16, 17, 18, 19). Also, both of them are very perishable and sensible to the biotic and abiotic threats. Hazelnuts have a good distribution range in Mures county and for harvesting, many tools are needed. The market demand is increasing, being cheaper than other forest fruits and more resistant at the negative action of risky factors, because of the wood shell and the huge capacity of drying. Pulp cones from *Juniperus* Genus require to have a good knowledge for harvesting and recognition (criterion 4, 8). The pseudo-beny are appreciated very well in pharmacology, being diuretics, diaphoretic and hypnotic. Bird cherries bring a good intensity of

importance in knowledge for harvesting process and also for recognition. Bird cherry have an amazing ornamental and the fruits are black, bitter, shiny and inedible (Șofletea and Curtu, 2007).

Table 1. AHP alternative ranking (Mureș County)

	Criterion	Berries							
		Rosa canina	*Quercus* sp.	*Rubus idaeus*	*Fragaria vesca*	*Juniperus* sp.	*Prunus padus*	*Corylus collurna*	*Sambucus nigra*
1	Harvesting period	8	7	4	1	5	3	6	2
2	Harvested quantity / worker / 8 hours	7	8	6	1	4	3	5	2
3	Harvesting cost	8	7	3	1	5	4	6	2
4	Knowledge for harvesting	5	6	1	2	8	7	4	3
5	Tools needed for harvesting	6	7	3	2	5	4	8	1
6	Complexity of harvesting process	4	8	3	1	5	7	6	2
7	Development of harvesting process	8	5	1	2	4	6	7	3
8	Knowledge for recognition	4	6	1	2	7	8	5	3
9	Distribution range	8	6	5	3	4	1	7	2
10	Biotic threats	5	6	7	8	1	2	3	4
11	Abiotic threats	3	5	7	8	1	2	4	6
12	Perishability	6	2	8	7	4	5	1	3
13	Market potential	5	1	8	7	3	2	6	4
14	Market demand	5	1	7	6	2	3	8	4
15	“Celebrity” of the product on market	6	1	8	7	3	2	5	4
16	The price of raw product	4	2	7	8	5	1	6	3
17	The price of the derived products	5	1	7	8	3	2	6	4
18	Portfolio of derived products	6	1	8	7	3	2	5	4
19	Transport (harvesting - storage center)	8	1	7	6	4	5	2	3

The higher mean (6) was obtained in the case of dog rose fruits (*Rosa canina*) because of the very strong importance intensity abundance in most of the criteria (figure 3) and the lower mean (3) was registered in the case of elder berry fruits (*Sambucus nigra*).

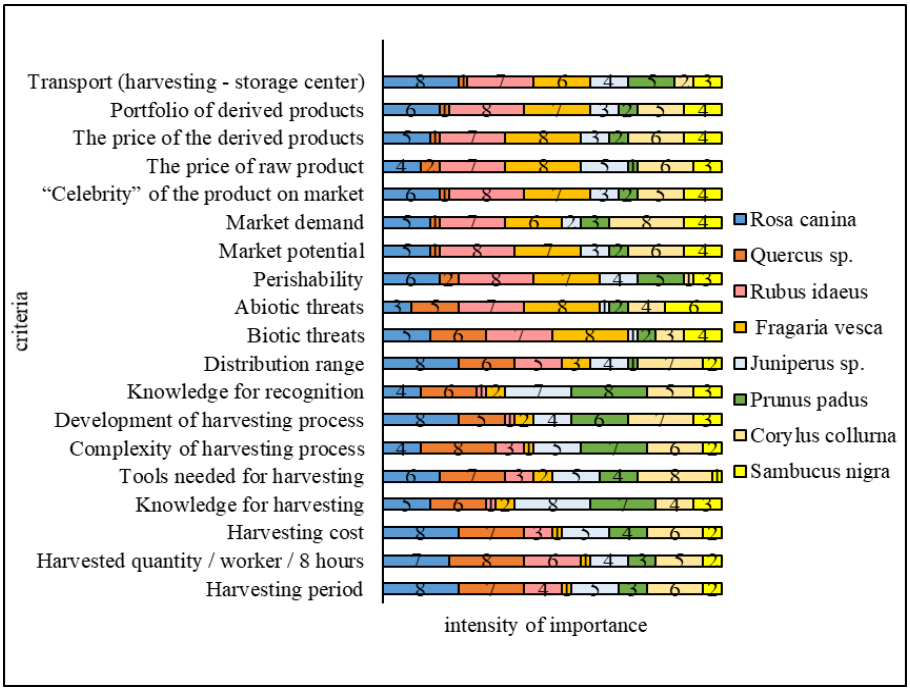

Figure 2. The intensity of importance for each criterion distributed on species

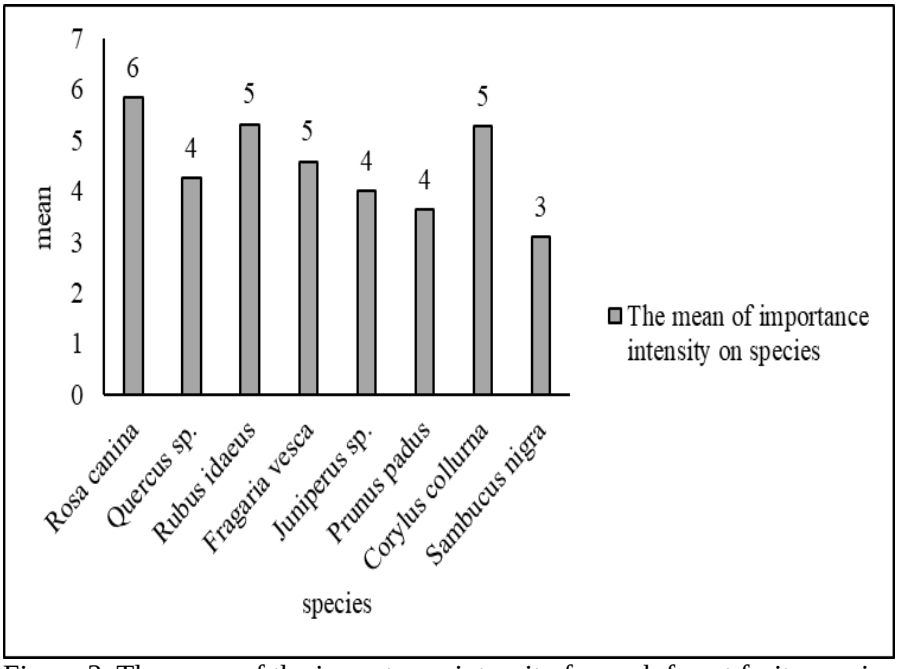

Figure 3. The mean of the importance intensity for each forest fruits species

The diagram of sensivity (figure 4) showing that the best results are attained by the dog rose (*Rosa canina*) being on the first place in the hierarchy because of the uses multitude and which manifest a lot of requirements regarding on harvesting process. The elderberry, instead of the fact that is easy to be recognized and harvested, he is situated below in hierarchy bringing equal, slightly or weak importance.

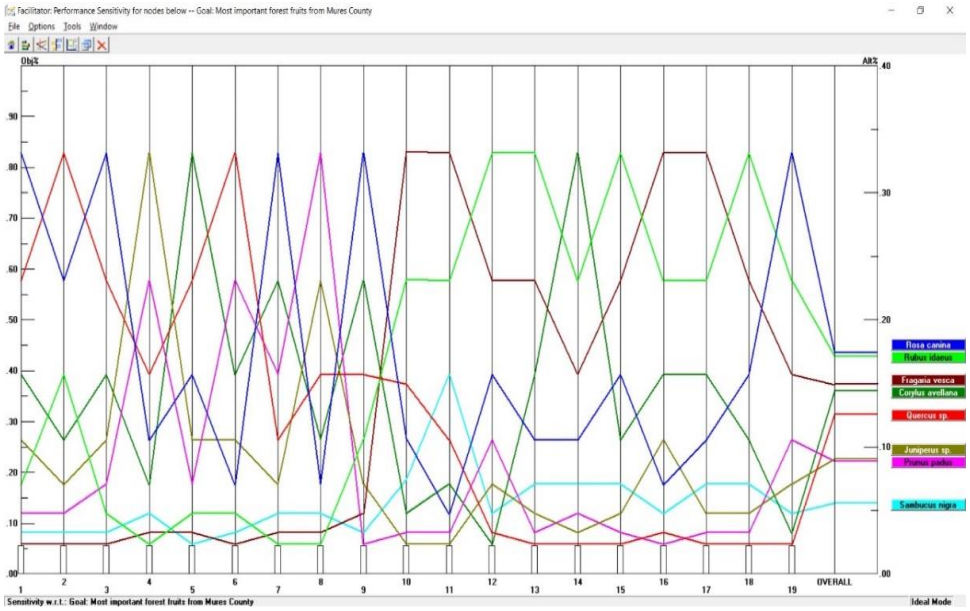

Figure 4. Diagram of performance sensivity in AHP ranking

The AHP was developed in positioning the non-wood forest product and evaluating the importance, especially on forest fruits, such as in the study carried by Enescu *et al*., 2017, in Maramures County, has positionated the raspberries on the first place in terms of importance, being very well represented in the external market (criterion 13, 14). In another study carried also by Enescu et al., 2018, in Timis County, according to AHP test, has situated *Boletus* Genus being the most promising and representative from the hierarchy, registering the very strong importance intensity in 8 types of criteria from the total of 19. In Bihor county, in the study carried by Timiș-Gânsac et al., 2018, from the category of mushrooms, the truffles were the most important non-wood forest products receiving an equal importance in all the 19 well established criteria. In the study carried by Bragă and Dincă, 2019, it was found that in Dâmbovita county, using the AHP, the most important forest fruits are raspberries, wild service tree fruits, dog rose and wild strawberry.

CONCLUSIONS

The variety of non-wood forest products constituted from forest fruits (mushrooms, nuts etc), spices, herbs, medicinal plants or game were used for human wellbeing, assuring food, medicine and cultural or social demands for millennia. The AHP method shows the importance of the most promising forest fruits included in the accessory products category, as well as the way of improving the sustainable management in Mureș County. According to the analysis implemented through AHP methodology, the most important forest fruits for this region are dog rose (*Rosa canina*), raspberries (*Rubus idaeus*), wild strawberries (*Fragaria vesca*) and hazelnuts (*Corylus avellana*). The results indicate that the study bring a lot of useful information about the way of exploiting the forest fruits, what kind of decision can be taken to implement an good harvesting management and how to build some strategies to improve the development of the economy in the rural areas by using the workforce of the local people favoring the positive effect for an sustainable management.

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COMMERCIAL BANKS AND THEIR EFFECT ON SMALL AND MEDIUM ENTERPRISES FINANCING IN RWANDA: A CASE STUDY OF KIGALI CITY AND SOUTHERN PROVINCE

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ABSTRACT

Commercial Banks worldwide are identified to be one of the key players in the financial industry that have positively affected individuals involved in business, and the economy at large, through the functions they perform in the economy. However, inadequate financing in the activities of Small and Medium Enterprises (SMEs) is still the major constraint faced by people involved in business activities. Even though the Government of Rwanda has made effort to improve the accessibility to credit, entrepreneurs still have some challenges to access financial services in order to improve their businesses. The purpose of this research was to assess the contribution of commercial banks in financing SMEs in Rwanda. A sample of 60 SMEs was selected in Kigali and Southern Province of Rwanda. Data was collected from the respondents through a structured questionnaire. The collected data were analyzed using descriptive statistics such as frequencies and percentage distributions. A Pearson Chi-Square Test was used to analyze the relationship between commercial banks and SMEs in Rwanda. The results indicated that the main purposes of loan application were start-up capital, working capital and expansion of businesses. The results also revealed that there was positive relationship between commercial banks and SMEs in Rwanda. The results revealed as well, that commercial banks in Rwanda played a crucial role in contribution to SME's economic development and small and medium entrepreneurs who got credit from commercial banks expanded their businesses and increased their income.

Keywords: *Commercial Banks, Small and Medium Enterprises, Entrepreneurs, Chi-square Test, Rwanda.*

INTRODUCTION

Commercial banks are the most important savings mobilization and financial resources allocation institutions and their roles make them an important phenomenon in economic growth and development (Olusanya et al., 2012). Commercial banks are considered as financial institutions that provide services,

such as accepting deposits, giving business loans and auto loans, mortgage lending, and basic investment products like savings accounts and certificates of deposit (Gockel and Akoena, 2002).

In Rwanda, commercial banks had focused on the improvement of communities' livelihoods. This is to be achieved by contributing to effective economic development activities for sustainable financial empowerment especially through small and medium businesses. Commercial banks constitute the anchor of the growth of other sectors by providing them access to credit facilities in the form of loans (Asantey & Tengey, 2014). Small and Medium Enterprises (SMEs) have been recognized as driving force for economic growth in developing countries. SMEs play a significant role in economic development and emerging markets. For SMEs to perform their role in the economy, they need adequate funds in terms of short and long-term loans (Ohachosim et al., 2013).

The Rwandan Small and Medium Enterprises policy is designed to complement a set of existing strategies with the aim to increase non-farm employment, develop business and technical skills in the Rwandan workforce, strengthen the financial sector and facilitate investment finance to generate industrial growth. The Government of Rwanda through its regulatory authorities, commercial banks will be able to increase entrepreneurship development. The recent poverty eradication program in Rwanda is focused on sustainable development through small business development, as the Government of Rwanda placed much interest on the development of the private sector, being the pillar of poverty eradication at all levels in the society (MINECOFIN, 2013).

The Government of Rwanda has concentrated efforts on implementing policies and programs targeted at enhancing the ability of SMEs and their entrepreneurs to access funding. Financial institutions, especially commercial banks, in Rwanda are one of the ways of reaching people who are involved in Small and Medium Enterprises (SMEs) for increasing their income and other self-employment activities by providing them credit. Commercial banks have been considered valuable if they provide credit facility to people. Banks financing SMEs face difficult financial constraints due to the lack of accurate reliable information on financial conditions of small firms. Banks hesitate to finance start-up and young firms, those with insufficient collateral, which demonstrate the possibilities of high returns but at significant risk of loss (Berger and Scott, 2005). However, inadequate financing in SMEs activities is still the major constraint faced by people involved in business activities.

Although the Government of Rwanda made effort to improve the accessibility to credit, entrepreneurs still have some challenges to access financial services in order to improve their businesses including financial credit accessibility. Commercial banks perceive SMEs as high risk and are therefore inflexible in terms of collateral accepted and repayment terms. This compound by the fact that most small borrowers lack experience and understanding of financial organizations and do not have the necessary skills to make successful applications. Despite this, there are funds, available for SMEs to assist in lending including funds for export

promotion, agricultural development and SMEs development, which are managed by National Bank of Rwanda (NBR) and the Rwandan Development Bank (BRD). The rapid development of accessing financial services has been a potential key to fight against poverty and build productive capacity, to compete to create job opportunities. Commercial banks can become truly sustainable for economic growth in the country. Despite increasingly important roles of commercial banks in poverty reduction, there have been relatively few studies that examine the role of commercial banks on small and medium enterprises in Rwanda. Therefore, this study seeks to assess the impact of commercial banks on SMEs financing in Rwanda.

MATERIAL AND METHODS

Study area

The study was carried out in March 2018 in Kigali City, Huye and Muhanga Districts of Southern province and where sixty Small and Medium Enterprises were clustered in production or manufacturing. Those SMEs were producing different productions. They were in production of foods, beer, iron sheet, organic pesticide, clothes, footwear, ceramics, and mining.

Data collection

The study used both qualitative and quantitative data from primary data sources to get information needed. Primary data were collected using structured questionnaires via SMEs manager's interviews and focus group discussion. Data were obtained using questionnaire to get the real information from Small and Medium Entrepreneurs and from commercial banks. The research design has been used to investigate how SMEs are affected by loans from commercial banks. Secondary data were obtained from different sources such as books, Government reports, RCA (Rwanda Cooperative Agency Report), theses and other documents relevant to the study.

Sampling methods

The sample used purposive sampling techniques to select 60 Small and Medium Enterprises in Kigali city and Southern Province of Rwanda. The study used the convenience sampling method to collect the relevant required data for analysis from the respondents.

Data analysis

The study used descriptive and correlation analyses to investigate the economic impact of the commercial banks on small and medium enterprises. The Chi-Square test method was used in this study to assess and investigate if there is relationship between the independent and dependent variable. The data were analyzed by using SPSS software and are presented in tables as frequencies and percentages.

RESULTS AND DISCUSSION

Description of different activities offered by SMEs in Rwanda

The table 1 presents the products and services provided by the SMEs assessed in the study area. Some of the SMEs are among manufacturing SMEs and others are among agro-based SMEs.

Table 1. Products and Services provided by SMEs in the study areas.

Products and Services provided by SMEs	**Frequency**	**Percent**
Agricultural products	8	13.3
Food products	12	20
Cement products	9	15
Brewery products	5	8.3
Metal products	4	6.7
Hygiene products	7	11.7
Organic pesticides products	3	5
Mining products	2	3.3
Clothing and footwear products	10	16.7
Total	**60**	**100**

**Source: Computed from field survey, 2018.*

The table 1 shows that food products have a highest percentage of 20 percent than other products while clothing and footwear products represent 16.7 percent. The remaining products and services provided by SMEs are still very few in the study areas.

Different source of the finance to Small and Medium Enterprises' start-up

Figure 1 presents different source of funds to finance the Small and Medium enterprises start-up in Rwanda.

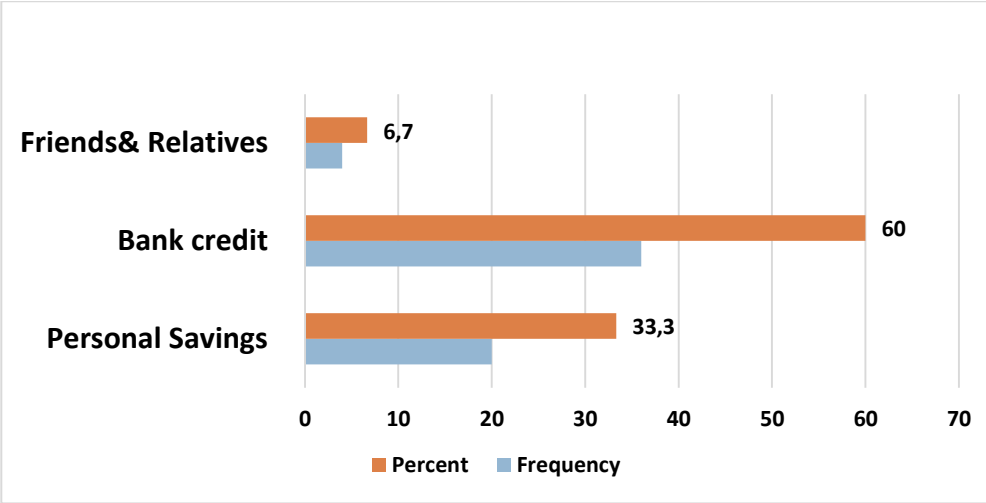

Figure 1: Source of finance to SMEs' start-ups.
**Sources: Computed by Author from field Survey, 2018*

Figure 1 above shows that 33.3 percent of small and medium entrepreneurs reported that they have used their personal savings to finance SMEs start-up while the majority of them 60 percent reported that they have financed their SMEs start-up from bank credits and only 6.7 percent of respondents that they have financed their SMEs from friends and relatives. From this result, we can indicate that the commercial banks in Rwanda have played a crucial role in financing SMEs especially in their start-up and their economic development.

Ranking of the relationship between SMEs and commercial banks in the study areas

The table 2 presents the ranking of the relationship between SMEs and commercial banks.

Table 2. Ranking of the relationship between SMEs' and Commercial banks.

Rank	Frequency	Percent
Excellent	22	36.7
Good	18	30
Average	12	20
Poor	8	13.3
Total	60	100

**Source: Computed by Authors from field Survey, 2018.*

The results indicate that 36.7 percent of SMEs entrepreneurs ranked the relationship they have with commercial banks as excellent while 30 percent of SMEs ranked the relationship they have with commercial banks as good.

However, SMEs have a positive and good relationship with commercial banks, it means that commercial banks are working adequately with SMEs in Rwanda.

Main purposes of loan application

The figure 2 shows the main purposes for loan application by SMEs managers.

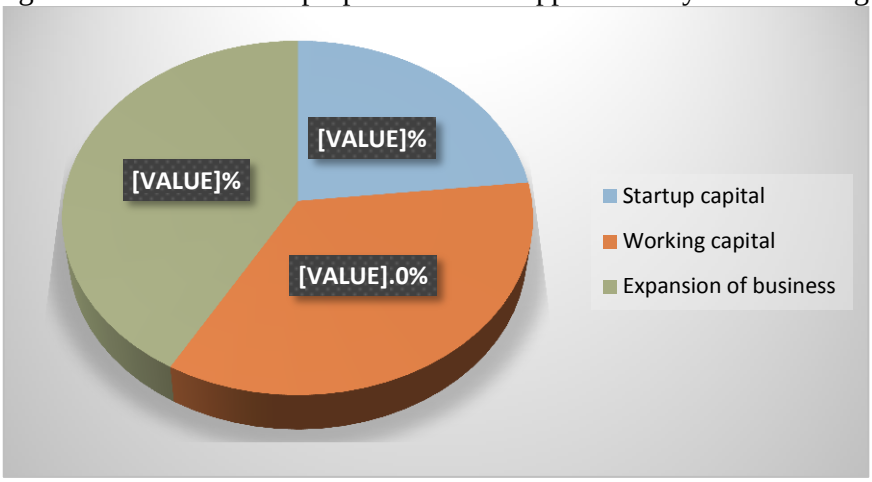

Figure 2. Description of the purpose of the loan application.

**Source: Computed by Author from field Survey, 2018.*

The results indicate that the main purposes of loan application were start-up capital, working capital and expansion of businesses. According to this figure 2, majority of entrepreneurs applied for loan to expand their businesses. However, the result show that 23.3% of respondents reported that they have applied for a loan for their start-up capital whereas 35% have applied loans for working capital and 41.7% have applied loan for expanding their businesses. According to the findings of this study, the majority of respondents applied for loan to increase their livelihood.

Major constraints to the growth of SMEs in the study areas

The table 4 shows the major constraints faced by households involved in SMEs activities. According to this table, the respondents showed their anxiety by giving constraints they face in the growth of their SMEs. However, 25 percent of the respondents reported lack of finance and credit as the main constraint to the growth of SMEs in Rwanda, whereas 15 percent declared market competition; 15 percent of the respondents stated that higher interest rate is a constraint to the growth of the SMEs especially those in agricultural and food production sector, 20 percent reported high taxes, 10 percent reported that raw materials are very expensive and 8.3 percent reported lack of markets of their products. However, in the study areas, the majority of the respondents reported lack of markets completion for their products. So, it is suggested that the Government and NGOs support small and medium entrepreneurs for improving their standards of living.

Table 3. Major constraints to the growth of the SMEs.

Major Constraints	Frequency	Percent
Lack of finance and credit	13	21.7
Market competition	15	25.0
Higher interest rate	9	15.0
Higher taxes	12	20.0
Expensive raw materials	6	10.0
Lack of market for our products	5	8.3
Total	**60**	**100.0**

**Source: Computed by Author from field Survey, 2018.*

Business experience after receiving loan from commercial banks

The results from figure 3 shows that 44% of the respondents reported that after receiving loan, their business has been improved in a positive way while 25% reported that receiving loan from the bank increased profitability in the company and their business has expanded, 19% of respondents reported that the income increased after getting loans as they gained more profit in the company and only 12% percent reported that there was no improvement in their companies after getting loan from the bank because they spent more time working for the repayment of the loan rather than working for the development of the business. As seen in the figure above, the majority affirmed that after receiving loan their companies improved.

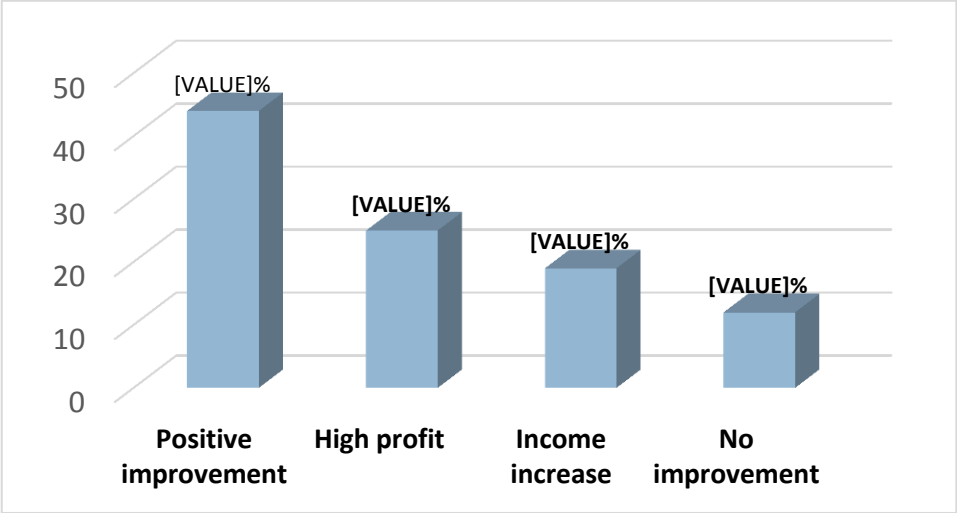

Figure 3. Impact of loan on business

**Source: Computed by Author from field Survey, 2018.*

Results from Pearson Chi-Square test

The Pearson Chi-Square was used to evaluate the relationship between commercial banks and monthly income, annual interest rate and repayment period of the credit got from commercial banks.

Table 4. Relationship between access to credit and annual interest rate.

Access to credit from commercial Banks	**Annual interest rate**			**Overall**
	Less than 15 %	**15-20%**	**20-25%**	
Yes	15 (25%)	11(18.3%)	8 (13.3%)	34 (56.7%)
No	10 (16.7%)	9 (15%)	7 (11.6%)	26 (43.3%)
Total	**25 (41.7%)**	**20 (33.3%)**	**15 (25%)**	**60 (100%)**
Chi-Square= $\chi 2$= 0.013				

**Source: Computed by Author from field Survey, 2018.*

The results from table 4 shows that 25% of respondents who have applied for credit reported that the annual interest were less than 15 percent while 18.3% of respondents reported that the annual interest rate was in the range of 15-20 percent and only 13.3% of respondents reported that the annual interest rate was in the range of 20-25 percent. The results shown after the calculation of the P-value revealed that it is equal to 0.013, which is less than 0.05. In this case, we accept the alternative hypothesis (H1) and reject the null hypothesis. This mean there is a significant relationship between access to credit and annual interest rate.

Table 5. Description of how SMEs rate their relationship with commercial banks according to the repayment period.

SMEs relationship with commercial Banks	**Repayment Period**				**Overall**
	Up to 1 year	Up to 2 Years	Up to 3 Years	Above 3 Years	
Excellent	13 (21.7%)	10 (16.6%)	2 (3.3%)	2 (3.3%)	27 (45%)
Good	5 (8.3%)	8 (13.3%)	7 (11.6)	1 (0.6%)	21 (35%)
Average	2(3.3%)	4(6.6%)	5 (8.3%)	1 (0.6%)	12 (20%)
Total	20 (33.3%)	22 (36.6%)	14 (23.3%)	4 (6.6%)	60 (100%)
Chi-Square= $\chi 2$= 0.050					

**Source: Computed by Author from field Survey, 2018*

Results from table 5 shows that for households who applied for loans with a maturity period of up to 1 year, 21.7% of them declared that the relationship with commercial banks is excellent while 8.3 % and 3.3 % declared that relationship

with commercial banks was good and average, respectively. As for households who applied for loans with a maturity period of up to 2 years, 16.6% of them declared that their relationship with commercial banks was excellent; 13.3% declared that their relationship was good and 6.6% reported that their relationship is average. Regarding households who applied for loan with a maturity period of up to 3 years, 3.3% of them declared that their relationship with commercial banks was excellent and only 0.6% and 0.6% declared that their relationship with commercial banks was good and average, respectively. The results also show that there is a positive relationship between commercial banks and SMEs. The table 5 shows also that the P-value is equal to 0.05, which is equal to 5 percent level of significance. This means that we accept the alternative hypothesis (H1) and reject the null hypothesis. In our case, the results indicate that there is relationship between commercial banks and the repayment period for loans. We can conclude that commercial banks have a significant impact on SMEs in Rwanda.

CONCLUSIONS

Small and Medium Enterprises (SMEs) in Rwanda have been recognized as driving force for economic growth and have been seen as very important way to escape poverty. This study analyzed the impact of commercial banks on SMEs in Rwanda and identified the relationship between commercial banks and SMEs. The results revealed that the commercial banks have played an important contribution to SMEs' economic development in Rwanda. However, the majority of the SMEs' Owners have reported that after getting loans from commercial banks, they have improved their businesses and their increased their income.

Therefore, the rapid development of accessing financial services has been a potential key to fight against poverty and build productive capacity, to compete to create job opportunity.

The study concludes that commercial banks have played a crucial role in financing SMEs especially in their start-up costs and their economic development and have a significant impact on SMEs in Rwanda. However, the major constraints to the growth of SMEs are markets completion, lack of finance and credit, higher interest rate in agricultural and food production sector, high taxes, raw materials which are very expensive.

With reference to the results of the study, the following policy implications have been given:

- Government should implement several programs to support the SMEs sectors in Rwanda.
- Government should support and help SMEs in various ways such as in accessing credit from different financial institutions, in organizing training programs for SMEs employees and promoting technological innovation for increasing their competitiveness at the market.
- Both public and private sectors should work together in order to develop SMEs sectors because of their contribution to the economic development and poverty reduction in Rwanda.

- Ministry of Commerce should facilitate business support services targeted especially at access to credit facilities for manufacturing firms and SMEs.
- The Government should implement policies in order to promote Made in Rwanda and market facilities of its products especially at regional and international level.

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AUTOCHTHONOUS BREEDS OF DOMESTIC ANIMALS AND CONSERVATION MEASURES

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ABSTRACT

Recently, highly productive breeds of various species of domestic animals have been used in livestock production, which has resulted in the destruction of indigenous breeds of domestic animals around the world, even in our area. This is the first reason why indigenous races and strains have been endangered. Another reason is that domestic, indigenous breeds were crossed with specialized breeds, which were imported, and in that way their genetic diversity was negatively affected. Resistance is lost, adaptation to the conditions in which they were created, the ability to survive in nature. Indigenous breeds of different species of domestic animals, which are recognized in the Republic of Srpska (B&H) are gatačko cattle and buša (cattle), Vlašić pramenka, Podveleška pramenka, Kupres pramenka (sheep), domestic Balkan horned goat (goats), Bosnian mountain horse (horses), mangulica (pigs) and pogrmuša hen or živičarka hen (poultry). By acceding to international conventions, B&H /Republic of Srpska has committed itself to establishing a system of measures that will enable the conservation of biological diversity and the protection of indigenous and endangered breeds of domestic animals. The choice of a strategy for the conservation of diversity, the establishment of an adequate conservation scheme, and the implementation of a conservation strategy are some of the key elements of any process for the conservation of genetic diversity. Preservation of autochthonous and protected breeds of domestic animals is possible through preservation in the original environment (in situ) and preservation outside the original environment (ex situ). There is a possibility of combining these models of conservation of animal genetic resources.

Keywords: *autochthonous races, in situ, ex situ, gene bank.*

INTRODUCTION

New times have brought the modernization of production in agriculture, which has affected the increase in productivity in all its areas, and therefore in animal and livestock production. Certainly, such production uses highly productive breeds of different species of domestic animals, which has resulted in the destruction of indigenous breeds of domestic animals around the world, even in our area. This is

the first reason why indigenous, traditional breeds and strains have been endangered. Another reason is that domestic, indigenous breeds were crossed with specialized breeds, which were imported, and in that way their genetic diversity was negatively affected. Resistance is lost, adaptation to the conditions in which they were created, the ability to survive in nature. All of the above are basic prerequisites for extensive cultivation (Taberlet et al., 2008). That is why there is a need to preserve animal genetic resources, which affect various aspects of a country (cultural, sociological, social, research, environmental).

The values of indigenous breeds of domestic animals are indisputable. These races influence the revitalization of rural areas through the creation of additional income for the local population. Then, they are suitable for the use and maintenance of pasture areas, prevention of devastation and succession of habitats (biotopes). When it comes to organic livestock production and the development of recognizable traditional brands, the inclusion of indigenous breeds is indispensable, a priority. They are an integral part of the ecosystem on which many other plant and animal species depend.

Preservation of indigenous breeds of domestic animals is possible through two models. The first model is preservation in the original environment (in situ) and preservation outside the original environment (ex situ). There is a possibility of combining these models of conservation of abnormal genetic resources. In order to approach the choice of models for the conservation of genetic resources, the factors on which these models depend must be respected.

The aim of this paper is, based on literature data, to point out the importance and role of genetic resources in animal husbandry, to present the autochthonous breeds of different species of domestic animals in the Republic of Srpska and to point out the measures for their preservation.

MATERIALS AND METHODS

The research was conducted in two parts. In the first part of the research, we will look at the importance and role of genetic resources in animal husbandry, then at the analysis of autochthonous breeds of different species of domestic animals in the Republic of Srpska and their degree of endangerment. The Law on Animal Husbandry of the Republic of Srpska from 2015 lists the recognized breeds and strains of different species of domestic animals, which will be described in the paper. In the second part of the research, we will point out the most important measures for the conservation of animal genetic resources.

RESULTS AND DISCUSSION

The importance and role of genetic resources in livestock

There are several reasons why the conservation and sustainable use of genetic resources in animal husbandry is necessary. In this paper, we will list some of the most important. The first of them is the socio-economic reason. The use of indigenous breeds and strains in livestock production meets the needs of the human

population in food as well as the needs of the industry for raw materials. In addition, in underdeveloped areas, livestock production is often one of the main sources of income and is the main driver of economic development in rural areas. The second reason is ecological, because the importance of genetic resources in animal husbandry is reflected in their role in the process of preserving the environment. The third reason is cultural-historical because indigenous races are part of the cultural and historical heritage. The importance of genetic resources in animal husbandry can be observed from both scientific and research aspects, which are reflected in specific sets of genes that usually possess indigenous breeds (disease resistance, longevity, acclimatization) and which are invaluable in the process of creating new and maintaining existing highly productive breeds, creating new breeding programs. Certainly one of the reasons that indicate the mentioned importance is the international obligation to preserve biodiversity. By acceding to international conventions, B&H /Republic of Srpska has committed itself to establishing a system of measures that will enable the conservation of biological diversity and the protection of indigenous and endangered breeds of domestic animals (Nikitovic et al., 2015).

Autochthonous races and strains in Republika Srpska (BiH)

The original and protected, i.e. autochthonous breeds of different species of domestic animals, which are recognized in the Republika Srpska (B&H) are the following: gatačko cattle and buša (cattle), Vlašić pramenka, Podveleška pramenka, Kupres pramenka (sheep), domestic Balkan horned goats), Bosnian mountain horse (horses), mangulica (pigs) and pogrmuša hen or živičarka hen (poultry), (Law on Animal Husbandry, Official Gazette of RS, No. 44/15, Article 40, paragraph 2).

Buša belongs to the group of short-horned cattle (*Bos brachyeros europeus*). Buša and its crossbreeds are located in undeveloped hilly, mountainous and karst areas south of the Sava and Danube. It was used for work, in the production of milk and meat. According to the appearance of the bush has a relatively small body, height at the withers up to 110 cm. Female heads have a body weight of 180 to 250 kg, and male heads about 300 kg. It belongs to the group of monochromatic cattle, and the shades range from gray, brown, red to black with a stripe on the back that contrasts with the base color. Buša is characterized by a dark pigmented mucous membrane with a light rim of hair around it - deer muzzle. The horns and hooves are always dark in color. Buša is late. Lactation lasts 9 months and gives about 1000 liters. In improved feeding conditions, it gives up to 3000 liters of milk (Adilović et al., 2014). It is characterized by good fertility and disease resistance. Other breeds, such as gatačko cattle, were created by breeding bushes and land reclamation work to improve production characteristics.

Gatačko cattle was created by breeding bushes with Viptal and Oberintal cattle. It is a short-legged beef, short-headed with a wide and uneven forehead. The muzzle is darkly pigmented with a light edge. The horns are thin, facing forward. The basic color is gray, it can also be brown, with dark shading on certain parts of the body.

Female necks weigh about 400 kg and males about 750 kg. Gatačko beef is most valued for its milk production, which goes up to 2,500 liters (Katica et al., 2004). According to literature sources, in this region, one breed of oats is autochthonous, ***pramenka***, with several strains: Vlašićki, Podveleški and Kupreški. Strains differ more in production, body weight, and wool quality than in morphological and physiological traits.

Vlašić pramenka is the most numerous strain of pramenka in BiH and is most represented in the vicinity of the mountain Vlašić. The body weight of females is about 35 kg, and males up to 60 kg. It gives up to 2.5kg of unwashed wool and 70 liters of milk plus 30 which sucks the lamb. It is known for the production of "Vlašić cheese" (Katica et al., 2004).

Podveleška pramenka is grown in the areas of Gacko and Nevesinje (Katica et al., 2004). The body weight of females is about 30 kg, and males up to 40 kg. They give up to 45 liters of milk and about 1 kg of wool per year.

Kupreška pramenka has lower wool production, up to 2 kg per year. The weight of sheep is from 35 to 40 kg, and rams up to 65 kg. It gives about 80 liters of milk. The domestic Balkan horned goat belongs to the group of Balkan primitives. The body is overgrown with a thick crest, and the color varies from black and white to black. Its head is long, its horns are double-edged and have the shape of a saber. There are also hornless individuals. The body weight of females is from 30 to 40 kg, and males up to 40 to 60 kg. Goats are kept for the production of milk, meat and fertilizers, and yet milk is their most important product. The average annual milk yield of our domestic goat is up to 130 liters (Adilović et al., 2014).

The Bosnian mountain horse originates from the wild horses tarpan and prževalski. By applying land reclamation, this horse was improved to a certain extent, but it still remained a pack, primitive domestic breed of horse with certain exterior features of tarpan, Przewalski and Arabian horse. Selection, breeding work on the domestic mountain horse began in the time of the former Yugoslavia (1908), in Bosnia and Herzegovina. Two male lines were created in the Bosnian hills: Miško and Barut, and eleven mares (from I to XI). The main breeding goal was to create as strong, bony and durable a pack horse as possible (Telalbašić and Žiga, 2008). Based on its appearance, this race has a more or less pronounced square body format. The height of the ridge is between 120 and 140 cm. The weight of adult heads ranges from 300 to 350 kg. The step is spacious, the gait is very careful and safe, especially when moving on the so-called. "Goat trails," similar to donkeys. The head bears the characteristic of the original forms inherited from the tarpan, the Przewalski and the Arabian horse. At the same time, it is easy to notice the Przewalski type when the head is more massive, with a more convex profile, narrow forehead, narrowed muzzle, and on the other hand the Arab influence on the finer forms of the head, while the tarpan influence on the appearance of the head was much smaller. The neck is moderately long, well set. The ridge is pronounced, high and long, the back is medium long, the lumbar part is short, and the joint is firm and short, and gives the horse a compact appearance (shape), which is the basic characteristic of pack horses. The croup is well developed,

slightly bent and square in shape. With good nutrition and care, the croup is round, round and fallen, and the root of the tail is usually low planted. The legs are relatively high (60% of the height at the withers), the shins strong, the hooves small but firm. Sometimes the hind limbs have a cow or saber stance. These foot positions are not considered a defect because it is a consequence of adaptation to movement on hilly - mountainous terrains. The most common hair color is dorata, then green, crow, tool, kulasa. Along the spinal column provides the so-called. eel lines, and on the front extremities a transverse stripe of darker or lighter coat color. The domestic mountain horse belongs to the primitive, late-race breeds. Its use value is significant considering that no other breed of horse is able to perform work in conditions where it is widespread.

Mangulica originated from the forest. There are 2 strains of mangulica: - white strain that was selected in Hungary and lasa strain that was selected in Srem. The white strain of mangulica predominates in size. It is a breed of moderately long and broad head that is large in relation to the body, has a slightly curved profile with a strong snout that is always pigmented. The ears are lowered, the neck is short, of medium length, the torso is short, the back line is carp, the croup is lowered shoulders and thighs are moderately pronounced, the abdomen is well defined and rounded, the legs are of medium length and the hooves are tightly pigmented, the abdomen is 10 tits.

The pogrmuša hen or živičarka hen can be found in the most remote mountainous areas, where it lives in an almost semi-wild state. According to its appearance, it is a small hen that can fly very well. The body weight of chickens is about 1 kg, and roosters about 1.5 kg. The color of the bush is black or partridge, and it can be multicolored. It is raised for its meat and eggs. It is late ripening, laying capacity of up to 80 eggs per year. The instinct for laying eggs is well developed. The breed is resistant and resistant to poorer conditions of nutrition, care and accommodation. It can be crossed with noble breeds of chickens, in order to improve their resistance.

Models of preservation of autochthonous breeds of domestic animals

The selection of a diversity conservation strategy, the establishment of an adequate conservation scheme, and the implementation of a conservation strategy are some of the key elements of any process for the conservation of genetic diversity (FAO, 2007). Republika Srpska does not have a gene bank for animal genetic resources. The preconditions for opening a gene bank to which genetic material will be deposited are not complete, so it is necessary to apply for projects related to this topic. Preservation of autochthonous and protected breeds of domestic animals is possible through preservation in the original environment (in situ) and preservation outside the original environment (ex situ). There is a possibility of combining these models of conservation of abnormal genetic resources.

In order to approach the choice of models for the conservation of genetic resources, the factors on which these models depend must be respected. Some of them are production (economic) competitiveness, population size (real, effective), degree of vulnerability (population trend, genetic structure, reproductive efficiency),

geographical distribution (dispersion) of the population, interest (sensibility) of the local community and the general public for protection.

In situ conservation model is the preservation of indigenous breeds by active cultivation in their original cultivation areas, which is the primary form of protection. In their original breeding area, the endangered breed will successfully maintain viability and exhibit production characteristics. In this model, the breeding program is envisaged and implemented, monitoring of merging and productivity is envisaged. In the case of small breeds, one of the major challenges will be to avoid or minimize inbreeding. Precise record keeping and strict mating control, which has already been mentioned, will especially contribute to this. The advantage of the in situ model lies in low investments, but also productivity in the environment in which the heads are located, and income can be generated on the farm. Precisely because of that, that is, because of maintaining contact with the environment, the term on farm method of preservation is introduced. This method of conservation can develop in several directions: control of the size, distribution and structure of the race; genetic consolidation and breed advancement; optimization of production systems and technologies suitable for indigenous breeds; animating the public and promoting race. In addition to the stated advantages of the in situ conservation model, which refers to the possibility of using the breed for food production, there is also tourism, education, preservation of traditional knowledge. It should be noted that this is a model of preserving live animals that does not require the inclusion of expensive materials, equipment, etc. On the other hand, the disadvantages of this model of preservation of indigenous breeds and strains are that you need to have land, labor, then there is the danger of losing population, part of the population or the entire population, due to disease or other disasters. In situ conservation programs implemented in domestic animal populations have been shown to be more or less successful, but need to be upgraded to avoid losing genetic variability (Matković et al., 2008). In conclusion, the in situ conservation model is more difficult to preserve genetic material, compared to ex situ conservation methods. The sustainability of this program lies in the creation of a breeding program on the farm, ie production on the farm, which usually refers to a traditional product.

The ex situ model of conservation of indigenous races is considered an important tool to avoid irreparable loss of races or genes. This model represents an approach to the protection of indigenous races outside their natural environment, which is the basic difference in relation to in situ conservation. Ex situ conservation or model of preservation of autochthonous races, basically takes place in two forms, namely: - Ex situ in vivo or conservation of live animals, by raising live animals outside their original area, such as zoos, museums, national parks, specialized farms, etc. Individuals from this model may possibly help the reconstruction of a breed, due to its extinction . - Ex situ in vitro or preservation of genetic material in gene banks, is the conservation of genetic material (sperm, eggs, embryos, stem cells) or criconservation. Tissue cells stored in liquid nitrogen enable partial or complete reconstruction of a breed in case of its disappearance, then it enables easier

recovery of the endangered population, reduction of the degree of breeding in the family, etc. The combination of in situ and ex situ conservation methods is the most reliable and efficient way of preservation.

Organizing in situ models of indigenous race conservation and ex situ conservation represents the formation of a gene bank. ***A gene bank*** is genetic material (gametes, eggs, sperm, tissue cells) collected, prepared, stored and stored appropriately in liquid nitrogen. Genetic material of races of local, regional and global significance is stored in the gene bank, in accordance with the selection and storage strategy (Čačić and Orehovački, 2014).

At the national level, the establishment of a gene bank should involve relevant institutions, and often non-governmental organizations. The genetic material stored in the gene bank is a public good, and accordingly the responsible services take care of its functioning.

The strategic reasons for establishing a domestic animal gene bank are the following: – support for in vivo programs for the conservation of indigenous breeds of domestic animals,

– have a backup of the population that would be used in case of a problem in in situ programs,

– increase in the effective size of populations, which results in a reduction in genetic loss,

– the possibility of reconstruction of the breed, whether it is an extinction of the population or a rapid decrease in the number of individuals due to disease or other disasters,

– creation of new lines or genera in case of their biological disappearance,

– population backup that can be used to modify the population,

– advisory role in animal population conservation and genetic management programs in small populations,

– conducting genetic and other scientific research.

CONCLUSION

Indigenous breeds of different species of domestic animals, which are recognized in the Republika Srpska (B&H) are the following: gatačko cattle and buša (cattle), Vlašić pramenka, Podveleška pramenka, Kupres pramenka (sheep), domestic Balkan horned goat (goats), Bosnian mountain horse (horses), mangulica (pigs) and pogrmuša hen or živičarka hen (poultry). By acceding to international conventions, B&H / Republic of Srpska has committed itself to establishing a system of measures that will enable the conservation of biological diversity and the protection of indigenous and endangered breeds of domestic animals. The choice of a strategy for the conservation of diversity, the establishment of an adequate conservation scheme, and the implementation of a conservation strategy are some of the key elements of any process for the conservation of genetic diversity. Preservation of autochthonous and protected breeds of domestic animals is possible through preservation in the original environment (in situ) and preservation outside

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ACCEPTANCE AND ADOPTION OF TECHNOLOGIES IN AGRICULTURE

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ABSTRACT

There is a need for transition towards sustainability in agriculture and food systems. New technologies and innovations can play a central role in improving agriculture productivity and sustainability. However, there is still a gap in understanding the factors that determine the acceptance and adoption of technologies in agriculture. Therefore, this review provides an overview on the main models and theories on the acceptance, adoption, use and/or diffusion of technologies. The most prominent theories and models include the Theory of Reasoned Action, the Technology Acceptance Model, the Motivational Model, the Theory of Planned Behaviour, the Innovation Diffusion Theory, the Social Cognitive Theory, the Social Construction of Technology, and the Unified Theory of Acceptance and Use of Technology. Furthermore, different combinations of these models have been used in technology adoption studies. These conceptual approaches and models span across disciplines (e.g. sociology, psychology, innovation, management) and differ in terms of theoretical assumptions, goals, variables and assessment methods. Factors determining the acceptance and use of technologies in agriculture are related to the technology itself and the ease of its use as well as social (age, gender), emotional, attitudinal and cognitive factors. Technology adoption is also affected by the environment and context in which it takes place. Technology acceptance models make use of predictors that are cognitive or relating to attitude, beliefs or perceptions. Some of the models focus on internal factors, such as antecedents of behaviour (e.g. values, attitudes, intentions), while others also address external issues (e.g. social norms, economic incentives, institutional environment). The framing of technology adoption within the wider Agricultural Knowledge and Innovation System (AKIS) offers interesting opportunities for fostering transition towards sustainability in agriculture. Indeed, technologies are just one component of AKIS and innovation

in agriculture also encompasses social, organizational, marketing and institutional fields.

Keywords: *agriculture, technology, technology acceptance, technology adoption, technology use, innovation.*

INTRODUCTION

Science, innovation and technology have a vital role to play in meeting the interweaved environmental, economic and social challenges facing humanity such as environmental sustainability, social justice, poverty reduction and climate change mitigation (STEPS Centre, 2010; United Nations, 2012). The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) highlights the important role of agricultural knowledge, science and technology (AKST) in addressing different sustainable development issues (e.g. poverty, food insecurity). The IAASTD (2009) points out that "*There is ample evidence available from the literature that AKST investments have contributed significantly to […] innovations in the form of methods, tools development, capacity strengthening […]*" (p. 516). The agri-food system is clearly associated to numerous sustainability challenges such as biodiversity loss, climate change, food insecurity, water scarcity (Bruinsma, 2011; FAO, 2014, 2016; Foley et al., 2011; IAASTD, 2009; Postel, 2000). Therefore, there have been many calls for sustainability transitions in agriculture and food systems (El Bilali, 2018b; FAO, 2017; UNEP, 2018). It is asserted that shifting towards sustainability in agri-food systems requires appropriate innovations and technologies (Bello & Aderbigbe, 2014; El Bilali, 2018; El Bilali & Allahyari, 2018; Singh et al., 2014).

New technologies that allow profitable and sustainable agricultural production are central for achieving food security (Loevinsohn et al., 2012). There are numerous promising new technologies and innovations in agri-food systems that can contribute to achieving food and nutrition security (HLPE, 2017; United Nations Conference on Trade and Development, 2017) such as precision agriculture technologies, ICT and nanotechnologies. Technologies that address the availability dimension of food security aims at improving agricultural productivity through, among others, enhancing soil management, breeding, irrigation (United Nations Conference on Trade and Development, 2017). Due to enhanced input/output ratios, new technologies are likely to increase output and decrease production costs, which leads, in turn, to a substantial increase in farm income (Challa, 2013). Low technology adoption rates cause low agricultural productivity and, consequently, food insecurity (Ngigi, 2003).

Nevertheless, it seems that the real challenge in agriculture is not only to have appropriate technologies and innovations but also to make sure that farmers/producers (as well as other value chain actors and rural populations in general) effectively access and use them (Wyckoff, 2016). Indeed, innovation diffusion and technology adoption are central themes in the agro-food sector (Avolio et al., 2014; Feder & Umali, 1993; Ugochukwu & Phillips, 2018). Loevinsohn et al. (2012) consider technology adoption as "*the integration of a new*

technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation" (p. 3). Webster (1969) defines a five-stage process of innovation adoption that starts with awareness about the existence of an innovation/new technology, through interest in the innovation, evaluation of the innovation using gathered information, testing and experimentation in real-world context, and ends with adoption. There is a host of literature on factors that affect technology adoption in agriculture (Antolini et al., 2015; Melesse, 2018; Mwangi & Kariuki, 2015; Ugochukwu & Phillips, 2018). Moreover, integration and adoption of new technologies is affected by technology acceptance, which is analysed by various models (Lai, 2017; Nejadrezaei et al., 2018; Sovacool & Hess, 2017; Taherdoost, 2018). The decision of farmers on whether to adopt a new technology is affected by the dynamic interaction between technology features and a host of conditions (social, economic, institutional, bio-physical) (Loevinsohn et al., 2012). Teklewold et al. (2013) and Melesse (2018) put that factors affecting technology adoption in agriculture can be grouped under (i) producer and farm characteristics (e.g. education level, experience, age, gender, level of wealth, farm size, labour availability, resource endowment, risk aversion); (iii) technology features (e.g. complexity, performance, cost, period of recovery of investment, susceptibility to environmental hazards); and (iii) institutional environment (e.g. availability of credit, access to information on the technology, infrastructure, extension support). This makes the technology adoption process quite complex and far from being straightforward.

Therefore, this review provides an overview on the main models and theories on the acceptance, adoption, use or diffusion of technologies. The paper comprehensively reviews the concepts, strengths and weaknesses of technology adoption theories and models. The most prominent theories and models include the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), Technology Acceptance Model (TAM, and its variants TAM2 and TAM3) (Davis, 1985; Davis et al., 1989; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000), Motivational Model, Theory of Planned Behaviour (TPB) (Ajzen, 1985; Ajzen, 1991b), Decomposed Theory of Planned Behaviour (DTPB) (Taylor & Todd, 1995), Innovation Diffusion Theory (IDT) (Rogers, 1995), Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). Further theories, which are not reviewed in the present paper, comprise Domestication Theory (Silverstone, 2006), Large Technical Systems (Hughes, 1987), Social Construction of Technology (Bijker et al., 2012), Social Cognitive Theory (SCT) (Bandura, 1986), Perceived Characteristics of Innovating Theory (PCIT) (Hameed et al., 2012). There are also different combinations of the above-mentioned models; for instance, hybrid TPB-TAM model suggested by Taylor and Todd (1995).

TECHNOLOGY ADOPTION MODELS AND THEORIES

Innovation Diffusion Theory (IDT)

The Innovation Diffusion Theory (IDT) or the Theory of Diffusion of Innovations (DIT), by Everett Rogers (1995), seeks to explain why, how and at what rate new

technologies and innovations spread. For Rogers (2003), adoption refers to the decision of "full use of an innovation as the best course of action available", while diffusion is "the process in which an innovation is communicated through certain channels over time among the members of a social system" (p. 5). As the above-mentioned definitions shows, innovation, communication channels, time and social system are the four key components of the innovation diffusion model. In this context, research on innovation diffusion attempts to explain the variables affecting the adoption of new technologies by users. IDT integrates three main components that are innovation characteristics, adopter characteristics and the process of innovation decision (Taherdoost, 2018). As for innovation decision process, five steps (viz. understanding, persuasion, decision, implementation, confirmation) take place, thanks to various communication channels, over a period of time (Rogers, 2003). Regarding innovation characteristics component, five main constructs have been proposed (viz. relative advantage, compatibility, complexity, trialability, and observability/results demonstrability) (Sila, 2015). As for adopter characteristics, Rogers (1995, 2003) indicates five groups of adopters: innovators, early adopters, early majority, late majority and laggards. The Perceived Characteristics of Innovating Theory (PCIT) (Hameed et al., 2012) expands IDT by adding three features viz. image, voluntariness and behaviour.

Since the 1960s, IDT has been used to study a wide variety of technologies and innovations, varying from agricultural machines to organizational innovations (Tornatzky & Klein, 1982).

It was used, inter alia, to investigate the adoption of land, soil and water conservation practices (Mango et al., 2017). IDT explains the adoption process and predicts the adoption rates (Askarany et al., 2012; Hameed et al., 2012), but does not consider how attitude and intention affect innovation adoption (Karahanna et al., 1999; Muchena et al., 2005). It focuses on the technology characteristics, personal attributes and environmental aspects but has less explanatory power when it comes to predicting adoption outcomes (Taherdoost, 2018).

Motivational Model (MM)

Since 1940's, various theories stemmed from motivation research. One of these is the Self-Determination Theory (SDT) developed by Deci and Ryan (1985). SDT posits that self-determination is a human quality involving choice experience, having choices and making choices (Deci & Ryan, 1985). Deci et al. (1991) point out that choice is the regulatory process when behaviour is self-determined, but compliance or defiance when it is controlled. Motivation theory supported the psychology research in explaining behaviour. According to Davis et al. (1992) the core constructs of the Motivational Model (MM), and SDT, are intrinsic motivation (cf. process of performing the activity) and extrinsic motivation (cf. outcomes distinct from the activity itself). For instance, Davis et al. (1992) suggest perceived enjoyment as an extrinsic motivation and perceived usefulness as an intrinsic motivation. Besides intrinsic motivation and extrinsic motivation, SDT also considers how the social environment affects motivated behaviours (Deci & Ryan,

1985). MM has been used in many motivational studies (e.g. learning, health care) (Gagné & Deci, 2005; Parijat & Bagga, 2014) but its application in technology acceptance and use is limited (Deci & Ryan, 2008).

Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) is one of the first technology acceptance theories. It was developed by Ajzen and Fishbein in 1975 (Fishbein & Ajzen, 1975) and has become one of the most fundamental human behaviour theories. The model of Ajzen and Fishbein (1980) aims to predict and explain any human behaviour. According to Ajzen and Fishbein (Ajzen & Fishbein, 1980), the core constructs of TRA are attitude toward behaviour, subjective norms (cf. social influence) and intention (i.e. behavioural intention). TRA represents the beginning of studies on behaviour focusing on the impact of attitude. Attitude is either one-dimensional or multidimensional factor and has direct or indirect effects on behaviour. Fishbein and Ajzen (1975) consider 'attitude' as the individual's evaluation of a technology, 'belief' as link between technology and some attribute, and 'behaviour' as an intention result (cf. use). Attitude is affective and influenced by a set of beliefs about the new technology. Subjective norms refer to the person's perception about the attitude of their immediate community towards a certain behaviour (e.g. use of a technology). TRA is a general model that was not designed to study any specific behaviour or technology (Davis et al., 1989). The theory does not consider other variables that effect intention like experience, fear and mood. Taherdoost (2018) puts that the main disadvantages of TRA are that it doesn't address the role of habit, cognitive deliberation and moral factors.

Technology Acceptance Model (TAM)

Unlike TRA, the final conceptualization of the Technology Acceptance Model (TAM) excludes the core construct of 'attitude' in explaining intention. TAM, which was first proposed by Davis (1985), includes fundamental user motivation variables (i.e. perceived usefulness, perceived ease of use) and outcome variables (i.e. behavioural intention, technology use) (Davis, 1989). Perceived Ease of Use (PEU) and Perceived Usefulness (PU) are considered the main variables/beliefs that explain intention and, consequently, behaviour (Marangunić & Granić, 2015). Generally, PEU refers to the effort relating to the use of a technology while PU considers the outcomes and advantages of using a technology especially in terms of performance. PEU and PU are accompanied by external variables explaining their variation; among others, self-efficacy (CSE), subjective norms (SN) and facilitating conditions (FC) (Schepers & Wetzels, 2007). External variables refer to contextual factors and personal capabilities. In the basic TAM model (Davis, 1985; Venkatesh & Davis, 1996), intention predictors included only two specific beliefs viz. PU and PEU. TAM2 extends TAM by including subjective norms as a further intention predictor (Venkatesh & Davis, 2000). The integrated technology acceptance model, TAM3 (Venkatesh & Bala, 2008), is the result of the

combination of TAM2 (Venkatesh & Davis, 2000) and the model of the perceived ease of use determinants (Venkatesh, 2000).
TAM was used to analyse the adoption of, among others, biological control on rice in Iran (Bagheri et al., 2016), mobile phones in Sub-Saharan Africa (Kabbiri et al., 2018), precision agriculture in Iran (Tohidyan Far & Rezaei-Moghaddam, 2017) and pasture-based grazing system in Ireland (McDonald et al., 2016).
The main limitations of TAM are that it ignores the social influence (cf. subjective norms) on technology adoption. Furthermore, factors relating to extrinsic motivations are not addressed in TAM, which makes the model inappropriate where technology use is not only to achieve specific tasks but also to meet certain emotional needs (Taherdoost, 2018). In order to address these limitations, in TAM2 social influence (image, voluntariness and subjective norms) and cognitive (e.g. result demonstrability, output quality) groups of constructs were added to TAM (Venkatesh & Davis, 2000).

Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB), first described in 1985 (Ajzen, 1985), is today one of the most influential socio-psychological models used in understanding human behaviour. TPB suggests that behaviours are already planned and extends TRA by adding the core construct of 'perceived behavioural control' (Ajzen, 1991b; Sheppard et al., 1988). Indeed, the core constructs of TPB are besides 'Attitude toward behaviour' (or 'behavioural attitude') and 'Subjective norms' (cf. TRA), also 'Perceived behavioural control' (Ajzen, 1985). Perceived behavioural control is determined by the availability of skills and resources as well as the perceived significance of those skills and resources to achieve outcomes. However, both TRA and TPB assume that an individual's behavioural intention (BI) affects their behaviour. TPB (Ajzen, 1985, 2005, 2012; Ajzen, 1991b) considers the behaviour of a specific consumer/user and provides a framework for analysing the determinants of such a behaviour. Briefly, 'intention' is the immediate antecedent of behaviour in the TPB. Intention, in turn, is assumed to be determined by three types of constructs or beliefs (viz. behavioural beliefs, normative beliefs, control beliefs). Behavioural beliefs refer to the perceived consequences of performing the behaviour and the subjective evaluations of these consequences. Behavioural beliefs lead to forming a positive or negative 'attitude toward the behaviour'. Normative beliefs relate to the perceived expectations of referent individuals or groups and they combine to create a perceived social pressure (cf. subjective norms) with respect to behaviour performance. Control beliefs regard the perceived presence of facilitating or hindering factors that affect person's ability to performing a behaviour. Researchers in different fields have added constructs to TPB to promote its behaviour prediction power (Burton, 2004). These include moral norms (Arvola et al., 2008; Kaiser & Scheuthle, 2003; Sandoghi & Raheli, 2017) and environmental concerns (de Leeuw et al., 2015; Sobhani et al., 2018; Yadav & Pathak, 2016). The Decomposed Theory of Planned Behaviour (DTPB) (Taylor & Todd, 1995) is a variant of TPB. It is identical to TPB in terms of

intention prediction, but – similarly to TAM – it decomposes the core constructs (viz. attitude, subjective norms, perceived behavioural control) into their underlying belief structure within the contexts of technology adoption.
TPB was used, among others, to analyse the adoption of soil conservation practices (Wauters et al., 2010), water conservation practices (Chaudhary et al., 2017; Yazdanpanah et al., 2014) as well as pesticides use (Bond et al., 2007). It was also utilised in different fields such as purchase of organic products (Arvola et al., 2008; Sobhani et al., 2018), dairy farming (Bergevoet et al., 2004; Rehman et al., 2007), forestry (Karppinen, 2005; Pouta & Rekola, 2001). Furthermore, different types of behaviours of producers were analysed thanks to TPB such as entrepreneurial behaviour (Bergevoet et al., 2004), conservation behaviour (Beedell & Rehman, 2000) and environmentally-oriented behaviour (Willock et al., 1999).
As for model limitations, TPB does not consider other factors that may affect behavioural intention to perform a behaviour such as experience. Furthermore, it does not take into consideration economic and environmental variables (Truong, 2009).

Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is one of the most prominent models in technology acceptance and adoption field. The UTAUT integrates various models on technology acceptance and adoption (Williams et al., 2015) such as Motivational Model (Deci & Ryan, 1985), Technology Acceptance Model (Davis, 1985), Innovation Diffusion Theory (Rogers, 1995) and Theory of Planned Behaviour (Fishbein & Ajzen, 1975). In its initial form, the UTAUT suggests that four main elements/core constructs – 'effort expectancy' (cf. perceived ease of use), 'performance expectancy' (cf. perceived usefulness), 'social influence' (cf. subjective norms) and 'facilitating conditions' – determine 'behavioural intention' to use/adopt a new technology and that these constructs are moderated by different variables (e.g. age, gender, experience, voluntariness of use) (Venkatesh et al., 2003). More recently, the UTAUT has been augmented with additional three core constructs viz. hedonic motivation (from consumer behaviour research), price value (from economics) and habit (from sociology), while 'voluntariness of use' was removed (Venkatesh et al., 2012).
Since its introduction, UTAUT has been widely used in innovation diffusion and technology adoption research. It has been utilised to study a variety of technologies with various moderators (e.g. gender, age, experience, education, income) and users (e.g. professionals, students, farmers). UTAUT was praised for its power to elucidate the factors determining the acceptance and use of a new technology. One key benefit of UTAUT is that it represents an encompassing and integrative model that synthesizes eight theories and models and counter their deficiencies and limitations. For that, despite being new, UTAUT is increasingly popular among technology adoption models (Al-Hakim, 2007). Furthermore, its validity, stability and viability in technology adoption surveys have been confirmed within numerous contexts. Unlike other models (e.g. TAM, TRA, TPB), UTAUT model explains

high percentage of behavioural intention to use a technology as well as effective technology use (Brown & Venkatesh, 2005). Therefore, Taiwo and Downe (2013) put that UTAUT "*is believed to be more robust than other technology acceptance models in evaluating and predicting technology acceptance*".

Although UTAUT is a robust model, it has some shortcomings. The limitations of the composing models affect the ultimate viability of UTAUT. These shortcomings relate, among others to the conceptualisation of the relation between intention (cf. behavioural intention) and use (cf. use behaviour). One further shortcoming of UTAUT is that it relies on a relatively narrow conception of the user (e.g. purchaser). Moreover, it does not specify the relative significance and weight of its different core constructs/constituent elements, nor does it capture qualitative aspects of technology acceptance (e.g. informal learning, interpersonal social networks) (Sovacool & Hess, 2017).

CONCLUSIONS

Adoption of innovations and new technologies in agriculture can not only have a central contribution to the achievement of food security and the improvement of the sustainability of agri-food systems worldwide but is also vital in achieving the targets of the second Sustainable Development Goal (SDG 2: Zero Hunger) in the framework of the 2030 Agenda for Sustainable Development. Moreover, deployment of appropriate technologies is crucial to address the pressing challenge of climate change. However, impacts depend on the level of acceptance by farmers/producers and the types of technologies adopted. For that, it is of paramount importance to understand the factors that affect the adoption of technologies in agriculture worldwide and to fine-tune the acquired knowledge to the specific context of each country. Therefore, this review provides an overview on the main models and theories on the acceptance, adoption and use of technologies. These conceptual approaches and models span across disciplines and differ in terms of theoretical assumptions, variables/constructs and assessment methods. Each model has its strengths as well as shortcomings and limitations. Factors determining the acceptance and use of technologies in agriculture are related to the technology itself and the ease of its use as well as social (age, gender), emotional, attitudinal and cognitive factors. Adoption of technologies is also affected by the environment and context in which it takes place. Nevertheless, it is important to highlight that technologies alone are not enough and that they represent only one of the components of the wide AKIS. Indeed, innovation in agriculture concerns many areas affecting the technological field (cf. technology adoption) as well as broader organizational, marketing and institutional areas. Furthermore, evidence shows that, besides technical innovations (e.g. new technologies), also social innovation significantly affects agriculture productivity and sustainability. Moreover, it is of paramount importance to pay attention to the environmental, economic and social sustainability of technologies used in agriculture, especially in the era of high-tech, precision and smart agriculture. It is also crucial to involve end-users (e.g. farmers, herders, fisher folk) in technology

development and validation to make sure that it is context-relevant, appropriate and accessible and to move towards more participatory models of 'technology transfer' in agriculture.

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