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Impact of mycorrhizal fungi on walnuts and grapes resistance to pathogens in Ukrainian orchards – a review

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Biological production practices are increasingly replacing chemical production practices to comply with guidelines for integrated production. This new approach is not only valuable above ground, the subterranean environment benefits equally from a bio-friendly approach. The mycorrhiza group of fungi is receiving more and more attention, since it allows roots to function in greater harmony with their environment. Mycorrhiza is a symbiotic association between a fungus and the roots of a vascular host plant. These symbioses are characterized by bi-directional movement of nutrients where carbon flows to the fungus and inorganic nutrients move to the plant, thereby providing a critical linkage between the plant root and soil. Nutrients taken up by the mycorrhizal fungi from the soil can lead to improved plant growth and reproduction. As a result, mycorrhizal plants are often more competitive and better able to tolerate environmental stresses than are nonmycorrhizal plants. In this review we discuss the research directions of the Ukrainian Institute of Nut Crops and other research institutes for organic production and the potential benefits of mycorrhizal fungi on walnut and grape plants growth and their resistance to several pathogens.
Keywords: mycorrhizal fungi; walnuts; grapes; organic production

Introduction

Biological production practices are increasingly replacing chemical production practices to comply with guidelines for integrated production. This new approach contributes to the subterranean environment benefit from bio-friendly approach. The mycorrhiza group of fungi become very popular in agriculture, since it allows roots to function in good balance with their environment. These fungi live symbiotically with the roots and involved in the uptake of nutrients in exchange for carbohydrates. As a result, the performance of the plant is considerably enhanced; mycorrhizal plants are often more competitive and better able to tolerate environmental stresses than are nonmycorrhizal plants. Mycorrhizal fungi increase uptake rates of nutrients by a variety of mechanisms, including increased physical access to soil, changes to mycorrhizosphere or hyphosphere, and alteration of the bacterial community in the mycorrhizosphere. They influence mycorrhizosphere chemical balance through release of organic acids and production of enzymes (Simard, 2002, Meyer, 2007, Farahani et al., 2008).

The distribution area of nut plants is 7% of the Earth's surface; the world's plantation area under nurseries is about $50 \cdot 10^6$ ha. The majority belongs to the dessert nuts: peanuts have 50% and coconuts – 25%. The area of the world plantations of the walnut (*Juglans regia* L.) is more than $6.23 \cdot 10^5$ ha, which annually grows about $1.5 \cdot 10^6$ tons of nuts. The largest producers of walnut are China (up to 10^6 tons) and the USA (California – $3.5 \cdot 10^5$ tons), annual gross collections which together reach more than 60% of world production. Large producers of walnuts are also Iran (up to $5.0 \cdot 10^5$ tons), Turkey (up to $2.0 \cdot 10^5$ tons), and Ukraine (more than $1.0 \cdot 10^5$ tons). The soil-climatic conditions in Ukraine are favourable for the walnut, hazelnut, almond, and chestnut growing.

Viticulture is a major worldwide economic sector with a total area of $7.52 \cdot 10^6$ hectares, wine production of 288 Mhl, and wine exports of 26 billion euros. Ukraine is also located in the grape-producing zone on the globe. In the south of Ukraine there are 15 macro regions, and 58 micro zones (Grape Cadastre of Ukraine, 2010), which produce unique types of wine products that are in greatest demand in the world. Ukraine has a unique opportunity to take one of the leading places among producers of

organic products due to its natural, climatic and soil potential. The current strategy of the Ukrainian government places the development of organic farming, processing and retail business among its top priorities.

Almost all the plant species in crop production exist in mycorrhizal association with fungi. Several studies have shown (Borowicz, 2001) that mycorrhizal fungi are better than roots at acquiring poorly mobile phosphate from the soil, which they exchange with their host plant for their sole source of carbon. In addition to their role in phosphate acquisition, mycorrhizal fungi have other potential benefits to plants like the uptake of important nutrients such nitrogen, protection against root pathogens, water acquisition and the mediation of pollution effects. Adapted as ecotypes to each other and to local conditions, the soil-climatic conditions of root systems of nuts and grapes allow the mycorrhiza fungi to be introduced into themselves, thereby using and controlling mycorrhiza. Simard (2002) calculated that mycorrhizal myxomycetes make it possible for plants with relatively small area of root biomass significantly increases the digestibility of consumer substances at the expense of up to 60-fold expansion of biomass of their hyphae and the area of settlement on the soil profile. Colonization of root systems of mycorrhiza determines and increases the level of photosynthesis in nuts and grapes.

In this review we discuss the research directions of the Ukrainian Institute of Nut Crops and other research institutes for organic production and the potential benefits of mycorrhirzal fungi on walnut and grape plants growth and pathogen resistance.

Walnut Production in Ukraine

In most countries on the planet, including Ukraine, walnuts are grown and processed on an extensive basis (except for the USA and France), so the data on the number of plantations and gross collections of products in most cases are determined by the calculation method. At present, hazelnut cultivation is also widespread in many countries of the world, but its production is most developed in Turkey, the USA, Italy, Spain, the Balkans, the Caucasus, the countries of Asia, and several European countries. In the world, the hazelnut nuts are in the third place. In Turkey, the nut plantations cover an area of $4.15 \cdot 10^5$ ha, which employ 10% of the able-bodied population of the country. The average yield is 10 centners per hectare, but modern varieties and technologies allow receiving up to 50 ql./ha. In general, the nut industry includes manufacturers in more than 30 countries of the world.

Production of walnuts in Ukraine has been relatively steady over the last three to five years and is expected to remain unchanged in the near-term. Commercial development of walnut acreage is ramping up since 2009. Walnut production in Ukraine is spread throughout the country. Various regions have been producing walnuts as well as hazelnuts for many years. Climate conditions and soil in Ukraine are suitable for growing nut trees. At present, about 85 percent of all walnuts harvested in Ukraine are produced by small private family farms. Three decades ago, when there was no private land ownership in Ukraine, walnuts were produced by collective farms in the Soviet planned economy. Some of those orchards still bear walnuts, though at much lower yields (Dubinyuk, 2014).

In Ukraine, the walnut selection and cultivation research work were carried out at H.M. Vysotsky Ukrainian Institute of Forestry and Agroforestry by F.A. Pavlenko, P.I. Molotkov N. (1978), I.P. Badalov (1983); at the Central Republican Botanical garden of the Academy of Sciences of the USSR by R.M. Tizh, N.M. Antonyuk (1984); at the Institute of Botany of the Academy of Sciences of the USSR by T. Ye. Strila (1982); at the Ukrainian Institute of Horticulture by A.H. Honcharenko (1983); at the Donetsk State University by F.L. Shchepotyev (1983), AR of the Crimea, at the Nikitsky Botanical Garden by A.A. Yadrov (1983), A.A. Revin (1976), at the Transdniestrian Experimental Station of the Bukovyna Institute by F.T. Zatokoviy, L.F. Satina, V.I. Saiko, M.K. Yoltukhovskaya (1986) and others.

Only at the Transdnistrian Experimental Station of the Bukovina Institute there were created 19 walnut varieties by the method of individual selection. At the same time, scientific researches on the interaction of plants in the orchards of the walnut crops, compacted by other perennial and annual crops, have not been carried out until now.

According to statistical data from 01.01.2016, in Ukraine there are 16.1 thousand hectares of nursery stands, including 15.8 thousand hectares of walnuts and 0.3 thousand hectares of hazelnuts. The yield of walnuts is 80.3 centners per hectare. Gross collection of nuts consists of 107.7 thousand tons. Agricultural enterprises account to 2.3 thousand hectares of walnuts, including 0.7 thousand hectares of fructiferous walnut, with a yield of 9.8 centners per hectare (Plots, gross collections and yield of crops, fruits, berries and grapes in 2016).

In 2012, Ukraine officially exported 28.6 thousand tons of nuts for 102 million USD. The largest importers are former CIS countries: Azerbaijan, Belarus, Kazakhstan, the Russian Federation, Moldova, Turkmenistan, and Uzbekistan – 3.8 thousand tons; Europe: Albania, Bulgaria, Bosnia and Herzegovina, Spain, Italy, Lithuania, Romania, and Slovenia – 0.6 thousand tons; Asia: Vietnam, India, Iraq, Iran, Islamic Republic of, India, Cyprus, Lebanon, Syria, Arabic Republic, and Turkey – 3.5 thousand tons; Africa: Algeria – 0.1 thousand tons; America: Belize – 2 tons; other countries – 20.7 thousand tons. In 2016, Ukraine exported about 35.1 thousand tons of nuts for a total amount of 66 million USD, including 12.2 thousand tons of shelled nuts for 12 million USD, 23 thousand tons of unshelled nuts for 54 million USD.

According to statistics, only 14% of nut crops from common areas are cultivated at agricultural enterprises. At the same time, the industrial value of nut crops is increasing in the areas of Transdnistria, Transcarpathia. The most widespread native plants in Ukraine are: walnuts, hazelnuts and almonds. The average annual volume of gross collections is from 80 to 100 thousand tons of nuts, with 99.7% of the total production of walnuts.

The increased demand for nut products has respectively increased the attention of business entities to nut production in recent years, which has become the main factor leading to an increase in areas planted by nut crops. Thus, over the past 5 years, Ukraine has planted 1,1160 hectares of nut crops at non-state agricultural enterprises, in particular: 180 hectares at the LLC "Velykokisnytske" of the Vinnytsia region, 210 hectares at the "Nika-A" and 7.7 hectares at the FH "Grek" of Mykolayivska region, 39.5 hectares at the LLC "Timiryazivske", and 15.3 hectares at the FH "Agro-Marin" of Odessa region, 50.2 hectares at the SFH

"Vira", Poltava region, 62.6 at the LLC "Gardens of Dnister", Khmelnytsky region and 594.6 hectares at the PE "Company Agloux" of Dnipropetrovsk region. It should also be noted that nut crops in Ukraine in most cases meet the criteria for organic products.

Grape and Wine Industry in Ukraine

Grapes are one of the oldest cultivated plants. Nowadays there are about 8 million hectares of grape plantations in the world, producing about 60 million tons of grapes. The largest area of grape plantations in Europe is over 5 million hectares (60%), in Asia – about 1.8 million hectares (20%), in Africa – 0.4 million hectares (5%), in America – 0.9 million ha (12%), and in Australia and Oceania – up to 0.1 million hectares (1%).
Average yield consists of 80 ql./ha. Worldwide table grape production is 7-7.5 million tons. The largest producers of table grapes are Turkey, USA, Italy, Chile, Spain, Japan, Brazil, Greece, Algeria, France, Iran, Syria, and Afghanistan (Fig. 1).

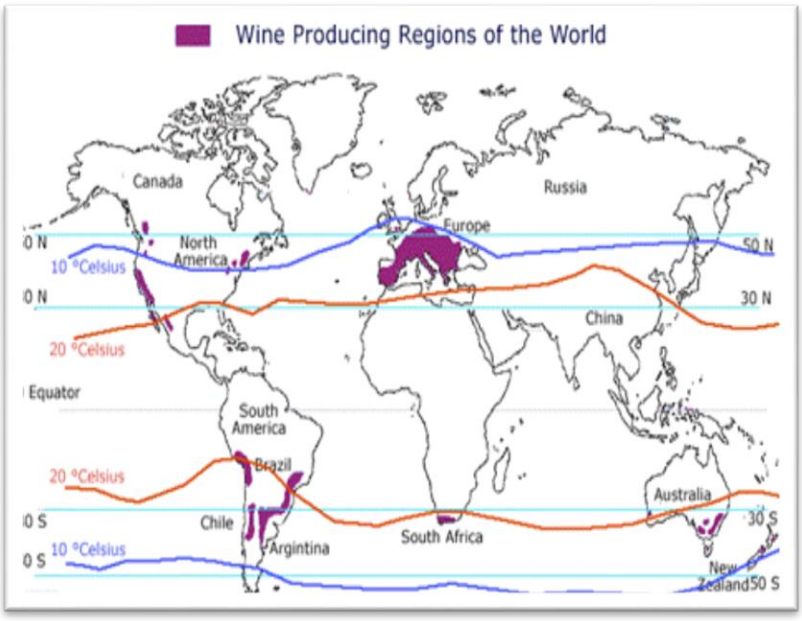

Figure 1. Wine-Producing Regions of the World

Ukraine is also located in the grape-producing zone, whereas principal zones of viticulture and winemaking are mainly located in the South of Ukraine. Therefore, one of the main directions of development for the southern regions is the extending of wine-growing and wine-producing industry (Fig. 2).

Figure 2. Principal zones of viticulture and winemaking in Ukraine

The Ukrainian total area of grape plantations was 103 thousand ha with a gross collection of 161 thousand tons in 1940. In 1975, these indicators were already 258 thousand ha and 1187 thousand tons respectively. As of 1 January 2016, in Ukraine there were 45.4 thousand ha of vineyards and 335.9 thousand tons of grapes were collected (plots, gross collections and yield of crops, fruits, berries and grapes in 2016). The factories of primary winemaking have processed 253 thousand tons of grapes and produced 16.6 million dl of wine materials, secondary wine-producing factories produced 18.16 million dl of wine production (dried-grape and fortified wines, sparkling wines and champagne, vermouth, brandy and cognacs of Ukraine) (Grape processing and production of wine materials in 2016).

The wine industry in Ukraine and in the World is currently shifting toward more sustainable production practices. The reasons for this include: the growing public concern over climate change; the increasing competition on the market; environmental values; an even more "green" consumer (Sirieix et al, 2010; Forbes et al, 2009; Heyns et al, 2014; Gabzdylova et al, 2009; Mueller et al, 2010).

In Ukraine, there are several wine-producing enterprises, which produce wine products in a certain segment that according to qualitative indices are not inferior to foreign analogues. In addition, domestic wines and their cost are cheaper, as many producers grow grapes in a specific southern climate with low air humidity with significantly lower pesticide load compared to similar plantations located in Western Europe. They are: OJSC "Koblevo", OJSC" Limansky "of Mykolaiv region, LLC "Shabo", LLC "Champagne of Ukraine" of Odessa region. These factors are positive ones of the overall component in the production of organic products of grapes and wines.

Organic Production in Ukraine

Numerous reports have emphasized the need for major changes in the global food system, toward organic farming, a system aimed at producing food with minimal harm to ecosystems, animals or humans (Godfray et al, 2010; Foley et al, 2011; Leifeld et al, 2010). According to a definition proposed by the International Federation of Organic Agriculture Movements (IFOAM), organic agriculture unites all agricultural systems that maintain ecologically, socially and economically advisable agricultural production. These systems make use of the natural potential of plants, animals, and landscapes and are aimed at the agricultural practices of harmonization with the environment. Organic farming significantly reduces the input of external production factors (resources) by putting a limit to usage of the chemically-obtained fertilizers, pesticides, and pharmaceutical preparations. Instead, to increase the yield and protect crops, organic farming employs other agrotechnical methods and various natural factors. Organic agriculture adheres to the principles that were formulated by the specific local social, economic, climatic, historical, and cultural features (Organic Agriculture and Food Security (Rundgren, 2002). The European Union Commission defines organic agriculture as follows: "organic agriculture ….pleads for the recovery of resources and recycling while restoring soil nutrients from waste products... When it comes to the control of pests and diseases in crops and livestock, organic agriculture respects the environment and avoids the use of synthetic pesticides, herbicides, chemical fertilizers, growth hormones, antibiotics and gene manipulation. Instead, organic farmers use a range of techniques that help sustain ecosystems and reduce pollution" (Tomic, 2010). Organic production is a system that integrates "cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity." It should exceed the indicators of the conventional agricultural production system in terms of yield, diversification and economic efficiency.

According to expert estimates, Ukraine currently has about one hundred eighty registered organic food companies, which operate at around 400,764 ha of certified organic farmland (1% of total arable lands in Ukraine). This is considerable below than in EU countries (for instance Austria uses 19.4% of it arable lands for organic farming), so there is a scope for growth. Given its geographical location, the country is well placed to cater the needs of the European Union (EU), the organic food market of which grew fourfold in the last decade (Usov, 2016).

The demand for organic products is far higher than supply, since organic products have food benefits primarily due to the absence of pesticides, herbicides, fungicides, residues of chemically synthesized fertilizers, GMOs and their derivatives (Cooperation and Organic, 2014). Ukraine has a unique opportunity to take one of the leading places among producers of organic products due to its natural, climatic and soil potential. Fertile black soils occupy 60% of the total area of arable land, about 8 million hectares of which are relatively clean and meet the criteria for organic production.

Several agricultural enterprises have already gained experience in agricultural production with the use of biological means for combating diseases and pests instead of pesticides and insecticides, the reproduction of soil fertility due to the application of soil protection technologies, the introduction of organic fertilizers, cedar seedlings, and a significant reduction in the use of mineral fertilizers.

In Ukraine, as of 1 January 2017, there are 210 certified organic farms with a total area of land use of 410 thousand ha. In addition, 530 thousand ha of wild plantations are certified in Ukraine (by IFOAM). Most Ukrainian organic farms are in Vinnytsia, Zhytomyr, Transcarpathian, Lviv, Poltava, Ternopil, Odessa, and Kherson oblasts (Fig. 3). Now there are 16 certification companies-non-residents, who carry out certification of agricultural production according to the rules of organic production adopted in accordance with the EU Regulation No. 834/2007.

The volumes of agricultural enterprises' sales of organic products in 2006-2007 amounted to about 600 thousand euros on average; by the end of 2014 they had reached a level of 14.5 million euros, in 2015 – more than 17.5 million euros and have a steady tendency for further growth.

The main types of organic products that are produced and consumed in Ukraine are fruits, vegetables, grain crops, meat and dairy products, cereals and bakery products, baby food. In 2016, the production of organic grapes and wines started at the enterprises of the Odessa region OJSC Agrofirma "Shabo" and FH "Black Sea Pearl".

Figure 3. Zones of organic production in Ukraine

In 2016, the Verkhovna Rada of Ukraine adopted the Law of Ukraine "On the Production and Circulation of Organic Agricultural Products and Raw Materials". Specialists of the Ministry of Agrarian Policy and Food of Ukraine, together with specialists of the representatives of NGO organic movement in Ukraine prepared a draft Law of Ukraine "On Basic Principles and Requirements for Organic Production, Circulation and Marking of Organic Products" and the Government approved and directed it to the Verkhovna Rada of Ukraine (registration number 5448 dated 24.11.2016).

As one of the steps aimed at realization of the strategic directions of development of agroindustry cluster, the Ministry of Agrarian Policy initiated project for the development of horticultural and winemaking branches of Ukraine.

The data of organic market analysts and certification bodies that certify organic production show that the products of nuts, grapes and wine have a significant demand both in the domestic and foreign markets, which makes it possible to develop these areas. Potential organic viticulture, winemaking and nuts help to harmonize economic, environmental and social goals in the field of agriculture in various regions of Ukraine, especially the densely populated southern ones. The emergence of small peasant and farm enterprises, grape-wineries of "Chateau" type with grae plantations and distilleries, compaction of fruit-bearing grape plantations with nuts, and walnut orchards with table grape and technical varieties expands the number of land users interested in obtaining environmentally safe products. Growing retail sector in Ukraine and large supermarket and hypermarket networks are ready to buy organic products of high quality from domestic producers: nuts and grapes of table varieties and factories of primary winemaking are ready to purchase certified organic grapes of technical varieties for its processing and further production of organic wines.

Influence of environmental factors on grapes and nuts

Ecological factors like abiotic (soil-climatic), biotic (interactions of living organisms) and anthropogenic (related to human activity) ones have several related effects on the effectiveness of cultivating grapes (*Vitis* L.) and walnut (*Juglans regia* L.), namely:

Abiotic Factors

• Cultivation area and climate. These crops are distributed within the geographical parallels from 200 to 540 latitudes of the Northern and Southern hemispheres with cold temperatures (up to -15, - 20 °C in winter), moderately warm (in winter not less than 12 °C), and hot (average annual temperature + 15 °C) (Perstniov et al, 2011).

• Evidence on the history and geography of cultures. According to de Candol and M.I. Vavilov, place of origin of cultural grapes are the countries of Southern Transcaucasia and Central Asia, as well as the neighbouring eastern regions (Iran, Afghanistan, Eastern China, and Asia Minor) (Negrul, 1956). M.I. Vavilov distinguished three centres of the natural distribution of walnut: the Chinese – the mountainous central and western China; the Central Asian – the North-Western part of India with the Punjab, Kashmir and the North-Western border provinces, Afghanistan, Tajikistan, Uzbekistan and Southern Kyrgyzstan; Central Asia: Malaya Asia, Transcaucasia, Iran and mountain Turkmenistan (Shchepotiev, 1987, p. 4).

• Orthogenesis. The cycle of plant development is similar. With seed propagation, the period of life lasts 250-300 years, with vegetative – 100 and more years. Fruiting happens on 5-7th year. Vegetation involves the same (Shchepotiev, 1987).

• Need for light. Plants are light-loving, but because of evolution they acquired the properties of growing in the shade with diffused light.

• Temperature regime of air and soil. The most favourable temperature for plant growth is 25-35°C. Vegetation begins in the spring. Required amount of active temperatures is from 1900 °C to 2800 °C for different groups of varieties.

In the degree of frost resistance, the varieties of plants are divided into 3 groups:

1. Relatively frost-resistant (to -24- 25 °C)
2. Medium-frost resistant (to -22-23 °C)

3. Low frost resistance (to -21-22 °C) The most valuable grape varieties for winemaking and high-yielding varieties of the lateral type of flaxseed of the walnut are common in the southern latitudes.

• Moisture of the soil and air. Optimum humidity of the soil during vegetation period is in the range of 70-85%, plants are sensitive to irrigation, artificial watering can optimize the soil moisture and air, and as a result, significantly increase the yield of crops. Optimal depth of groundwater is 2 meters. Optimal air humidity is 60-65%

• Soil factors: Cultures can be grown in all types of soils except waterlogged and saline ones. Optimal conditions for soil alkalinity are in the range of 6.8-8.3 pH.

• Food regime. Due to long-term growth in a permanent place and an annual take-off with each ton of products of 5-8 kg of nitrogen and potassium, 1.5-2.5 kg of phosphorus, 50-70 g of iron, 40 g of copper, 10-15 kg of chlorine, 15 g of manganese, 8.0 g of boron, 6.0 g of zinc, and other micro- and macro elements (Perstniov et al, 2011), they require periodic replenishment by fertilization.

• Structure of the root system. In nature, grapes and nuts have a root system of rod type. In industrial culture, plants propagate vegetative by the most widespread way of winter grafting. Therefore, the nature of the root system changes from the rod to mucosa, which is weaker and less durable, but fully satisfies the needs of practice, provides high yields of a grape bush or walnut tree for 80-100 years (Dikan et al, 2011).

• Non-waste production. From grapes: fresh grapes, soft sparkling wine, champagne, alcoholic cognac (cognacs, brandy), non-alcoholic beverages, products (concentrates, vacuum mustard, honey, sugar, juice, compote, marinade, jam, candied fruits, etc.), kishmish, raisins, yeast (feed yeast, ether), seeds (entotanin, oil), roots (vinegar), forage flour, tartaric acid, anti-dandruff. From nuts: ripe nuts, a high-calorie and nutritious food. Used in the manufacture of medical preparations, confectionery, butter, flour, tinctures, marinades, jam, cosmetics, varnishes and paints, wood is used in the production of musical instruments, furniture, folk crafts, and weapons. The shell is used in the production of activated charcoal, grinding stones, linoleum, etc. (Buriak & Pakhno, 2011).

• Medicinal properties. Since ancient times, the walnut has been considered a good remedy that can cure the effects of the most severe poisoning. Therapeutic and preventive drugs, presented in the domestic pharmaceutical market, are recommended for use as antimicrobial, anti-inflammatory agents for various diseases (Buriak & Pakhno, 2011). Along with the high usefulness of grapes as a food product, it is also valued and used in medicine as a therapeutic product for ampelotherapy (grape cultivation). Ampelotherapy was used by Hippocrates, Pliny, doctors of the Arab world and doctors of the Middle Ages. They cured colds, coughing, fever, used grapes for tumours and wounds. Somewhat later, ampelotherapy was used against anaemia, against acute inflammations of the respiratory tract, diseases of the lungs, kidneys, liver, rheumatism, arthritis, gout, cardiovascular diseases, exhaustion of the nervous system and fatigue (Perstniov et al, 2011).

Biotic Factors

Root systems of plants actively interact with populations of archeas, bacteria, fungi, protozoa and animals that live in the root soil zone and function together with plants (Hadzalo et al, 2016). At the same time, root systems of plants, including walnuts and grapes, evolved in such a way that they could enable rhizospheric fungal groups (Tuberaceae, Glomeromycota, Glomales, Ascomycota) to be introduced into themselves, thus forming symbiotic associations and interacting most effectively with them. This type of symbiosis (symmetric for the benefit of both plants and fungi), called mycorrhiza, functions as a component of the chain in nutrients and energy flows between plants and soil. Fungal pathogens and mycorrhizal fungi also interact with each other. Many studies have shown that significant protection of plants from pathogens is due precisely to the presence of the root system of mycorrhiza (Harwani, 2013). Studies of the interaction between mycorrhiza and fungal pathogens have shown that plants usually grow better when their root system is populated with mycorrhiza, which allows plants to counter pathogen infection (Borowicz, 2001). Adapted as ecotypes to each other and to local conditions, the soil-climatic conditions of root systems of nuts and grapes allow the mycorrhiza fungi to be introduced into themselves, thereby using and controlling mycorrhiza. Simard (2002) calculated that mycorrhizal myxomycetes make it possible for plants with relatively small area of root biomass significantly increases the digestibility at the expense of up to 60-fold expansion of biomass of their hyphae and the area of settlement on the soil profile. Colonization of root systems of mycorrhiza determines and increases the level of photosynthesis in nuts and grapes.

Anthropogenic Factors

Human activities cause increased nitrogen deposition in a variety of ways, including burning of both fossil fuels and forests, fertilizing crops with nitrogen-based fertilizers, ranching, during which livestock waste releases ammonia into the soil and water, allowing sewage and septic tanks to leach into streams, rivers, and groundwater (Hadzalo et al, 2016). According to an ongoing temperature analysis conducted by scientists at NASA's Goddard Institute for Space Studies (GISS), the average global temperature on Earth has increased by about 0.8 °C since 1880. Two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15-0.20 °C per decade (NASA, 2010). As the climate has warmed, some types of extreme weather have become more frequent and severe in recent decades, with increases in extreme heat, intense precipitation, and drought. The influence of these factors on the livelihoods of nuts and grapes and their mycorrhiza is unpredictable.

Directions of research of the Ukrainian Institute of Nut Crops

Walnut (*Jugiane regia*) is a chemical factory with a well-established production of many important substances. Juglone is a well-known component of walnut, however, it is found in considerable amounts in all green and growing parts of trees and unripe hulls of the fruit (Prasad, 2003; Topal et al, 2007). Several biological high-level compounds give the leaves, wood and root system the properties of an effective bactericide. For this reason, traditional medicine has long been using decoctions of leaves and green nuts to treat many diseases. It was not until the 1850s that juglone was first isolated from the walnut tree, and in 1881

the first scientific report on juglone's allelopathic effect was published (Stickney & Hoy 1881). Juglone (5-hydroxy-1,4-naphthoquinone)) is a natural compound (the group of naphthoquinones) that is contained in the form of glucoside in the nut tree (about 1%) (Zhunhiyetu & Vlad, 1978). The study of its content in different parts of the walnut tree, depending on the season, showed that its largest content was in the buds in the state of winter tranquillity (Daglish, 1950). In the leaves, roots and stems of the walnut tree, juglone was also found, in addition, its maximum content was in leaves (Lee et al, 1963). The class of quinones in its structure belongs to cyclic diketones, in their molecules the keto groups are connected by double bonds, and the nucleus of naphthalene lies at the basis of the molecule (Zhunhiyetu & Vlad, 1978). Therefore, juglone is of interest for a more detailed study, since it has the properties to be toxic to spores of fungi during their germination. At the same time, it also has allelopathic effects of selective nature on certain plant species. Along with this, on vine plants that grow in a nut orchard, juglone has a symbiotic effect, and transmits nut properties of increased resistance to disease and pests to grapes.

Nowadays, a significant amount of scientific research is aimed at studying the role of mycorrhiza in rhizosphere processes when interacting with a plant and another biota in anthropogenic abiotic conditions. In addition, there are still many issues related to the level of mycorrhiza diversity, the stress resistance, nutrition, and the use of photosynthesis products (Hadzalo et al, 2016). As the mycorrhizal symbiosis physically and chemically forms the rhizosphere of both plants and therefore has a definite influence on the community of walnuts and grapes, experts of the Ukrainian Institute of Nutrient Cultures have begun research on the influence of these factors on the immune system of plants, as well as the mechanism and participation of mycorrhiza in the process of synthesis of naphthoquinones, juglone. The research is carried out both in laboratory conditions (Fig. 4) and in the walnut and grape orchards of the agricultural enterprise "Gospodarul Rediu" of the Republic of Moldova (Figure 4) and FH "Nuts 2012" of the Izmail district of the Odessa region. When observing the development of plants in these massifs, the specialists of the Institute noted that mycorrhiza of nuts, like mycorrhiza of grapes, affects the growth and survival of walnut trees and shrubs of grapes. Attention deserves the fact that mycorrhiza influenced the resistance of both plant species to diseases and pests. The Gospodarul Rediu AH planted the Isabella grape variety with a land scheme of 3m x 2.5m in 2010, and consolidated this massif with annual walnut seedlings with a land scheme of 15m x 12m in 2007 to convert the vineyard to a nut tree orchard.

Figure 4. Investigation of mycorrhizal root systems of nuts and grapes in laboratory conditions

In spring of 2014, specialists of the FH "Nuts 2012" of the Izmail district of the Odessa oblast used 100 vine bushes of table varieties to compact 50 ha plantation of young nut trees planted in 2012 under the scheme of 20m x 20m. In 2016, the first crop of grapes appeared on the bushes. At the same time, since the time of planting the grapes, no spraying of bushes was carried out for protection against pests and diseases. However, vineyards that grow outside the garden, due to the presence of signs of diseases such as melliferous (*Peronospora viticola* de bari), oidium (*Oidium* tuskeri berk), etc., required 4 to 6 treatments annually with fungicides. Also, the Ukrainian Institute of Nutrition Cultures is observing the state of planted walnut trees, including young ones compacted by various cultures, located in different enterprises of different soil-climatic zones of Ukraine.

Figure 5. Walnut and grape plantation in winter and autumn

Conclusion

Considering the above said, it is possible to draw a preliminary conclusion on the expediency of further studying the influence of mycorrhiza on the increase of the properties of walnut and grapes for protection against a complex of pathogens, as well as the introduction of technology of compaction of fruit bearing grapes as an integral part of the technology of biological protection of these plants from pests and diseases. Specialists of the Institute are also planning to explore the interaction of mycorrhiza of the root system of walnut trees on one of the main pests of the root system of European grape varieties – phylloxera (*Dactylosphaera vitifoliae*). It should be noted that the detailed study of the above-mentioned processes and their scientific substantiation is especially relevant for the further introduction of positive results in the cultivation of organic products, and this direction of agricultural production in Ukraine tends to be actively developed. This applies to the production of walnuts and organic table grape varieties, as well as technical grapes for the further production of organic wines. It should be noted that in the ecological farm LLC "Kovcheh", which in Dnipropetrovsk region, during the winter vaccination season of walnuts, in the year 2015, spores of the symbiont of all nut crops began to occur: black truffles (*Tuber melanosporum*), mycorrhiza with oak and less often with other deciduous trees, directly into the seed containers of graft walnut. Since the main functions of mycorrhiza are the provision of plants with high-quality nutrition and water, stimulation and regulation of fruiting, the creation of a complex ecosystem that allows the joint survival of various plant species and protects plants from pathogens of different origins, isolating a large number of antibiotics of the group of naphthoquinones, in particular juglone, which suppresses these pathogens, the introduction of the above-mentioned measure, according to specialists of the enterprise, should significantly improve immunity and accelerate the rooting, especially in poor soils. It should also improve the properties of plants in terms of water absorption, drought tolerance, winter resistance, resistance to diseases and accelerate the maturation of the tree shoots and increase the amount of sugar and vitamins in the fruits.

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