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Organic Walnut Cultivation in Intensive and Super-Intensive System—Sustainable Investment. Case Study: Gorj County, Romania

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Abstract: The interest of the countries with traditions of walnut cultivation to increase the quantity and quality of walnut production is due to the fact that the organic cultivation of walnut is a sustainable business, with an ecological, economic and social impact. The walnut plant (Juglans regia) is a resource for food, dermatocosmetic and phytotherapeutic products, is raw material in the wood industry and a source of biomass. It is a species suitable for organic farming, with no chemical factors input (in line with the EU program to reduce pesticide use and fuel consumption by 35% in the context of the current energy crisis), and has properties of atmosphere purification and air-conditioning. Due to the creation of varieties with high production potential, suitable for cultivation in intensive and super-intensive plantations and also due to the government financial support, walnut plantations can contribute to the development of new valorization directions for the obtained production, by processing fruits and other vegetative organs (green nuts, green and dried shells, foliage, timber) with significant profits. In order to establish and capitalize on a walnut plantation in the pedological and climatic conditions of Romania, pedological studies, worthiness and pedoclimatic studies were carried out in the depression area of Gorj County and show the stages of cultivation technology in intensive and super-intensive systems. The sustainability and economic efficiency of setting up organic walnut cultivation has been highlighted in view of the costs for agrotechnical works, labor and material expenses. According to the analysis of the efficiency indicators, it has been shown that the establishment of an ecological walnut orchard, on an area of 1 ha, in Gorj County, Romania, is a sustainable, appropriate and opportune investment, in terms of capitalizing on the agricultural potential of the land, environmental protection and with social and economic impact.

Keywords: Juglans regia; culture; technology; efficiency; sustainability

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1. Introduction

The walnut tree (Juglans regia) is an important source for food, medicines, phytotherapeutic products, raw material in the wood industry, and biomass, called since ancient times "the magic tree". It is a fruit species that belongs to the Juglandaceae family, originating from the geographical area of the eastern Balkans, the Himalayas and South-West of China, and spread in temperate and Mediterranean areas, in spontaneous flora and actively cultivated [1]. The largest plantations are located in Kyrgyzstan, Arslanbob, Jalal Abad province, where walnut forests exist up to altitudes of 1000–2000 m [2].

The walnut was introduced into cultivation long before our era, first in China, then in Japan and India, in the Roman times' Europe, reaching America, in the 17th-century. Nowadays, the area in which the various species of the Juglandis grow spontaneously is over a relatively narrow strip of land on the globe, encompassing the extremity of the Balkan Peninsula, part of the Caucasus, some areas of China and Japan, and extending

toward the ocean in the northern part of America (California), Peru, Brazil, Chile, New Zealand, South East Australia, Europe (France, Serbia, Greece, Bulgaria, Romania)) [3–6].

The interest of all countries with a tradition in walnut cultivation to increase their production is evident when comparing F.A.O. data published in the Statistical Yearbook of 1990 (when fruit production was 893,287 t) with recent outputs (over 1.6 million t, the US ranking first (with 190,500 t), followed by China, Turkey, Iran, Ukraine, France). An important producer is the Republic of Moldova (over 20,000 t nuts/year), which also owns the largest plantation in Europe, whose area is estimated at 3000 ha [7–15]. The quantitative and qualitative growth in recent years is due to the creation of varieties with high production potential, suitable for cultivation in intensive plantations (reaching 400 trees/ha, compared to 100–120 trees/ha in classical culture) [11,13], as well as to the finanstates' financial support (for example, in France, a large nut-producing country, the state stimulates producers by providing a share of the expenses incurred on planting) [10,16].

In Romania, one of the largest walnut producing countries in the world, the walnut tree is a reference species, being known since ancient times [17,18]. Existing data confirm perpetuation of the species in the Carpatho-Danubian space. The millennial existence of the walnut was highlighted by the studies conducted by Sziladi Zoltan in the Orşova region of Mehadia, which proved the walnut presence since the tertiary era. Even 2000 years ago, Ovidiu exiled to Tomis wrote about the walnut "less demanding, this tree grows right on the roadsides and is not afraid of anything, neither wind, nor thunder, rain or heat". Until the First World War, the walnut ranked 3rd, after apple and plum, in terms of number of trees in orchard, production obtained and importance in the country's economy [17,18]. The wide spread of the walnut had in the past also turned into toponymy, many localities being named in this sense: Nucet, Nucetul, Nuci, Nucșoara.

Starting with 1958, research and development activities started about the walnut cultivation in Romania. The existing isolated trees grown from seeds produced questionable quality fruits, heterogeneous in size and disease resistance. Among these plants there were also valuable biotypes, which were selected and propagated vegetatively, by grafting, the first native walnut varieties being obtained within the Fruit Research Station Geoagiu, Hunedoara County, bearing now the area designation (Geoagiu, Sibișel, Germisana) [19–22]. After 1960, research on breeding for variety development started at the Research and Fruit Production Station Târgu-Jiu, Vâlcea, Piteşti, Mărăcineni [23,24]. In 1961, Romania ranked 4th in the world in terms of production, accounting for 7.2% of the world production, and in 1998, ranked 3rd in the world in terms of export of nuts. The severe frosts in the winters of 1940, 1941, 1962, 1963, associated with the deforestation of the walnut tree during the cooperativization of agriculture, led to a decrease in their number, from 3,625,000 trees in 1938 to 2,000,000 trees in 1993 [18].

In the context of intensification of the walnut cultivation in Romania, 18 walnut tree varieties and two rootstocks have been approved, the technology of producing grafted stock material was developed and new aspects were approached regarding the cultivation technologies [23,24]. Thus, after 1990, fruit companies specialized in grafting walnut trees, equipped with appropriate equipment for new technologies, being supported with subsidies from European Union or national government. In 2001, the walnut production in Romania was 25,000 t nuts in shell, representing 2.04% of the world production, placing Romania on the 9th place in the world, after China, USA, Iran, Turkey, Ukraine, India and France [23,25]. Since 2010, thousands of grafted seedlings have been produced, mainly with Romanian varieties, through which was laid the foundation of intensive walnut plantations, with an area of up to 100 ha (Nucifere Regio SRL Targu-Mureș) [26]. The impact of the European funds that Romanian farmers benefited from had a positive impact on the planted areas and on the obtained production. According to the statistical data provided by the Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu Şişeşti" Bucharest, Horticulture Department, until 2022, projects for walnut trees for an area of 5746 ha (64% of the total) have been financed; another 1352 ha of walnut and hazelnut plantations have been approved as eligible, but not funded yet [25–28].

According to data from the US Department of Agriculture, USDA statistics show that Romania has become the main producer and exporter of nuts in Europe. In 2017, there were 1.8 million registered trees, and at the end of 2021, 2 million trees were inventoried. Moreover, according to the data of the National Institute of Statistics (NIS), in 2021 production reached 56,300 t nuts in shell, from which were exported to Germany and Austria, 7148 t kernel (for which were collected 34.8 million Euros), but also nuts in shell (for which approximately 139,300 Euros were collected) [16,27].

Currently, in Romania the walnut grows spontaneously, solitary or in mixed orchards, in the hilly area, in all regions of the country (especially in Banat and Oltenia), where the average annual temperature is 8–11C and the minimum in winter does not fall below −24 °C [20,29]. The greatest walnut production is found in Alba, Gorj, Vrancea, Iași, Prahova, Argeș, Bacău, Bihor, Vâlcea, Arad and Maramureș [30,31]. In the Gorj County, located in south-western Romania, walnut represented one of the specific fruit species, with history and cult, spread as a result of the natural factors favorable to the growth and development of this fruit species; the hilly area has a climate with Mediterranean influence, favoring the growth of walnut species (walnut, edible chestnut, hazelnut) and even fig trees. The statistical data presented by the Târgu-Jiu Fruit Research and Production Station in 1975 show that at Gorj county level, the number of walnut trees was 59,329, of which 40,949 were scattered (69%) (inventoried in rural areas Padeş, Peștișani, Novaci, Baia de Fier and Polovragi with over 1200 trees each) and 18,380 trees in massive plantations. The Târgu-Jiu Fruit Research and Production Station had the genetic basis for selection and created the varieties Novaci, Peștișani, Victoria, Șușița, productively valuable and with higher quality indices, which have been approved and applied for the creation of commercial plantations [4,17,21,23,24].

In Romania, the walnut is on an upward trend and has special perspectives, because the establishment of a walnut culture, cultivated and exploited, with production obtained according to modern technologies, contributes to the sustainable development of rural areas. This business is in the preferences of farmer entrepreneurs interested in a long-term investment, by cultivating agricultural land with species with high technological life and with support from the European Union or the Romanian Government [28,30–33].

Establishment an organic walnut plantation, in an organized system, is sustainable and economically effective, as the walnut is a fruit-growing species, which although it grows slowly and comes into the fruit production phase relatively late, presents the following advantages:

- has rapid growth since the 3rd–4th year after planting, it is long-lasting (50–80 years) and after 10–12 years, offers large yields [17,18,23];
- is a fruit species suitable for organic plantation, free of chemical factors from chemical fertilizers and plant protection products, which are air, edaphic environment and groundwater pollutants, meeting the EU program to reduce pesticide and fuel consumption by 35% (in the current context of energy crisis) [11,28];
- is a fruit species with potential to occupy uncultivated areas and to employ surplus labor;
- is part of the support for investments to restore the orchard patrimony, by applying new strategies for implementing European and national agricultural policies; due to its well-developed roots, it is of importance in agroforestry improvements, in combating soil erosion and as protective shield [34];
- benefits from additional subsidies grants by AAPI (Agency for Agricultural Payments and Intervention) and of some facilities in the acquisition of high-performance equipment for plantation maintenance, harvesting, storage and fruit valorization (processing capacities are developed for fruit valorization: fruit dryers, vacuum packing line for nuts, storage warehouses) [35,36];
- the fruits are not perishable and can be kept for long time, without energy consumption, and the walnut kernels have special quality characteristics and represent about 50% of the weight of the nut in shell, depending on the variety;

- presents opportunities for production valorization (kernels for consumption in fresh, dried or in processed form, delivery of packed kernels with other dehydrated fruits, ground, walnut oil, honey and walnut kernels mixture) [34];
- the walnut oil is also used in the technical field, due to its siccative properties (for manufacture of typographical ink, varnishes and luxury soaps); the remaining paste after oil extraction contains 48.5% protein substances, 9.55% fats, 6.76% cellulose and 5.76% ash, used for halvah processing and as concentrated food for animals [34];
- the dried shell is used in industry to prepare activated carbon, grinding stones and other mixtures; there is currently great interest in the use of nutshells for heating the living spaces, instead of using pellets which are more expensive and have lower calorific value [32,33];
- walnut shoots are used for the extraction of tannins, phytoncides and etheric oils; walnut leaf branches are used in households for the ecological control of lice in poultry [34,37,38].

The importance of the walnut as a sustainable fruit plant (technical, forestry, medicinal, breeding, income-generating) is presented in the sub-chapters of this paper, structured as introduction, literature review, ecological characteristics and requirements, materials and methods, results and discussion.

2. Literature Review

The economic and social importance of the walnut is shown by studies that have researched the ecological impact of this tree species, through its properties of purifying the atmosphere, tempering air currents (wind) and keeping the environment clean [39,40].

Walnut also contributes to the development of new valorization directions of the obtained production, by processing the fruit and other vegetative organs of the plant, with significant profits (including obtaining of income from immature fruit, by processing green walnuts, green shells and leaves, in the form of traditional green walnut jam, green walnut liqueur, cosmetics and phytotherapeutic products) [34–36].

The dried shells and timber can be used to produce biomass, traditional, decorative and furniture objects (walnut wood being very massive, valuable and durable). Walnut wood is of superior quality (hardness, strength, smoothness, color) and given its natural veneer is used in the manufacture of luxury furniture, in sculpture, and for artisanal and decorative objects [32–38]. For this reason, between 1936 and 1960, many isolated secular walnut trees were felled, their number being reduced. Nowadays, the timber supplied from intensive and super-intensive plantations will no longer be of particular interest, as the trunks are less than 1–1.5 m high and less than 40 cm in diameter [4,9,10,12,16].

Numerous specialized studies on the chemical and nutritional composition of the walnut kernels demonstrate their therapeutic benefits and effects. The quality of walnuts is ensured by the diversity and high value of the component substances, which play an important role in the metabolism of the human body. Fresh walnuts contain 17% water while dried nuts do not contain water. The fruit is known as walnut kernel, and its content of the main components provides a balance in nutrition, with the recommended optimal daily intake being 28 g nuts, which is the equivalent of 4 nuts, containing: calories (73 g), fat (16 g/63%, of which 9 g unsaturated fat), protein (5 g/61.2%), carbohydrates (6 g/14%), monounsaturated fatty acids, Omega 3: alpha linoleic acid), fiber (3 g), vitamins (12–25%, of which: A, 4 mg%, B1, 0.35 mg%, B2, 0.1 mg%, C, 15 mg%, E, 12% of daily requirement, F, P, niacin, 1 mg%), minerals (Fe 21 mg%, Zn, Cu, 23%, Mg, 16%, Mn, 26%, Se, 56%, P, 430 mg%, K, 545 mg%, Ca, 70 mg%, salts Na, 4 mg%) and 13,500 ORAC (Oxygen Radical Absorbance Capacity units = autoxidative capacity per 100 g of food, walnuts ranking second after pecans, originating in South America, with 18,000 ORAC) [41–48].

Regular consumption of walnut kernels (30 g/day, 5 days/week), or of walnut oil (3 teaspoons), increases immunity, reduces the risk of type II diabetes (consumed regularly), promotes healthy teeth (due to its high P content), prevents and alleviates prostate cancer (by reducing insulin-like factors IGF-1, the main triggers of prostate cancer), stimulates

memory and brain function (due to the content of Omega 3 acids), reduces the risk of cardiovascular diseases, reduces depression, Parkinson's and Alzheimer's diseases (due to the presence of Omega 3 acid and of high melatonin content), and lowers thyroid hormone absorption (due to the presence of Se) [49–52]. Walnut oil obtained by pressing walnut kernels and consumed in a quantity of 60 mL in the evening is recommended for elimination of tapeworms, kidney stones and for regulating the urinary tract [53]. Green walnuts are a source of vitamins and minerals and have a fat content of 57% (100 g green walnuts consumed as jam equals 580 calories; green walnuts juice, obtained by macerating for 3 months 100 g green nuts and 100 g sugar, is used to treat kidney disorders). Vitamin C, tanning substances (gallic acid, ellagic acid), coloring substances and phytotherapeutic substances are extracted from green walnuts [34,54].

Walnut leaves have been used since ancient times for numerous remedies in the form of syrup, wine, tea, alcoholic extracts (in the treatment of syphilis, hemorrhoids, tuberculosis, for the reduction of blood glucose level, or in combating diarrhea), as dermo cosmetic and phytotherapeutic products (in the treatment of eczema, herpes, excessive sweating of hands and feet, hair loss) [50–55]. The walnut shell (endocarp) is a by-product containing 15% protein, 60% saturated fat, 2.4% fiber and used as tea or extract, constitutes a remedy in the treatment of cough, respiratory tract diseases, stomach infections, to remove warts, and in urinary tract infections [41–43,45–52].

3. Characteristics of Walnuts and Ecological Requirements

The walnut is a vigorous tree, that grows up to 30 m tall, with a thick trunk and smooth, silvery-grey bark. The branches are strong, the crown is very wide and rich, the leaves are made of 5–9 elliptical leaflets and have entire glabrous margins. It flowers in May. The male flowers are grouped into male gametes (solitary or in pairs) and are cylindrical and multiflorous. The female flowers are clustered in groups of 2–4 and are sessile, solitary and purple. The fruit is spherical, with a single, wrinkled seed, with two large, oil-rich cotyledons (nuts). It multiplies hard by seed (Figure 1) [1,3,4,11,17,18,30,31].

Figure 1. Botanical characteristics of the walnut tree.

The plantation requirements are differentiated according to the environmental factors, variety characteristics, plantation systems and technologies. Under Romanian conditions, the walnut cultivated in a technologically organized system, is subject to restrictions due to the geographical factors, relief, soil, humidity and temperature. The requirements of walnut with respect to environmental factors vary according to variety, age, rootstock, presence or absence of fruits and growing or dormant phase. Compared to other cultivated fruit species, walnut has a more restricted plasticity showing higher requirements with

regard to heat, light, humidity and soil types, which are limiting factors in its expansion. Being a very vigorous species, it has high soil nutrient and water requirements, which is why in areas with annual average rainfall below 650–700 mm, irrigation is a mandatory agrotechnical measure [56–62].

The growth and fruiting of walnut occur under the influence of the following factors [3,4,11,29,34,63]:

- hereditary
- ecological (with a direct effect on growth and fructification)
    - biotic
    - climatic (water, air, light, temperature)
    - soil (pedological: nutrient content, soil physical-chemical properties, water, air, microbiological activity)
    - organic
- Relief—restrictive factor, given the slope of the land (land with a slope greater than 10–12% cannot be used for walnut plantations in conditions of productive performance and economic profitability), the degree of soil fragmentation, the level of fertilization [17]
- Soil—the natural fertility and the production potential of the soil depends on its physical, chemical and biological properties: texture, thickness of the penetrable layer for roots, structure, depth of groundwater [64–66]
- Texture—soils are classified into:
    - sandy lands (with low natural fertility, lacking structure, high permeability for water and air; they heat up easily and lose water easily through evapotranspiration and infiltration; walnut plantations are productive in regions with normal rainfall, groundwater at depths of 1.5–4 m, on semi-movable sands, weakly humiferous sands with a humus content of 0.6–1% and over 5% clay; they require the application of organic fertilizers)
    - loamy lands (most suitable for walnut cultivation, as they allow a good development of the root system, can store and retain water, allow infiltration of excess water, are well aerated, warm easily and contain nutrients)
    - clayey lands (having a clay content of more than 45%, are compact, hardly permeable to water, aerated, acidic, moist, cold, rich in nutrients, difficult for roots to penetrate, unsuitable for fruit species; they have disadvantages in terms of poor root growth, show small and unreliable harvests, prolonged growing season until late autumn, low frost resistance)
    - swampy, salty, stony, calcareous lands (with an active limestone content of 8–10%)—not suitable for walnut cultivation
- Thickness of the penetrable layer for roots—as more than 50% of the roots are between 20 to 120 cm in the ground, the depth of root system should be between 1–1.5 m.
- Chemical properties of the soil [3,17,64–66]:
    - humus content—if below than 2%, adversely affects growth and fruiting; low humus soils, strongly eroded, podzolic, clayey-loamy or soils with too high content of organic matter, black meadow soils, do not ensure the balanced growth and development of the walnut;
    - soil reaction—acid pH favorable (between 5.5–8.5), with an optimum 6.2–7.5; at the alkaline level, accumulates Ca and Na and at acidic level, Mn;
    - mineral element content (nitrogen, phosphorus, potassium, calcium, iron, boron, magnesium, zinc, sulphur, copper);
    - high content of harmful salts (chlorides)—has low tolerance in their presence.
- Groundwater level—below 2.5–3 m depth
- Temperature—walnut is a heat-demanding tree species, temperature being a growth factor on which the processes of assimilation, respiration, transpiration, phenophase growth, dormancy during winter depend; walnut grows efficiently in regions with

average annual temperatures of 9.0–10.5 Celsius degrees (optimum temperatures of the species = 15–28 Celsius degrees, minimum = 7 Celsius degrees and maximum = 40 Celsius degrees; outside these temperatures, the growth ceases) [29,37,58,60].

Walnut cultivation is dependent on the absolute minimum winter temperatures and less on the annual average temperatures (8–17 Celsius degrees). Early autumn frosts cause the premature leaf drop and shoot tips' degeneration, preventing tissue maturation and its preparation for winter; spring frosts cause damage when flower buds are sensitive, temperatures less than −2 Celsius degrees during flowering causing destruction of the floral organs; walnut plants are also affected by maximum temperatures above 35 Celsius degrees in July-September. Since both the minimum temperatures in winter and the maximum temperatures in summer cause damage to the bark of the tree (cracks), the trunk must be protected by whitening [29,59,60,62,67].

- Water requirement—water is the vegetation factor with a decisive role in the life of the tree, as it is part of all its organs (75% in leaves, branches and roots and 85% in fruits) [68]. Drought affects shoot growth, leaf development, fruit quality and the life span of active roots. Under severe and persistent drought conditions, even though walnut is a long-lived species, due to its highly developed root system, its vigour decreases, the regularity of production and size of harvests decreases, trees age prematurely and their life span is shortened. Excess moisture is not favorable because it affects soil aeration and slows down normal root activity, especially on clayey-loamy soils with poor drainage. Water requirements depend on the age of the tree, size of the crown, size of the root system, concentration of nutrient solutions in the soil, structure and humidity of the soil, amount of atmospheric precipitation, wind speed, intensity of light, size of the plantation and slope of the land. Walnut needs water during the first growing season, during the shoot and fruit growth and less during flowering, fruit ripening and leaf drop.
- Light requirement—light is very important in the photosynthesis process, in the growth speed and formation of the aerial organs of the plant, in the respiration and transpiration of leaves, in the growth direction of the shoot. In Romania, light as an aspect of intensity (measured in lux) and duration (number of hours with sunshine) is sufficient to ensure optimal technological conditions. In order to ensure sufficient quantity and intensity of light, walnut plantations should be planted on sloping lands with south, south-west and south-east exposures, ensuring that the optimum planting distance is sufficiently large to prevent shading each other.
- Air requirement—carbon dioxide is important in assimilation, and oxygen in respiration of the aerial and subterranean organs; the permanent movement of air in the walnut plantations is thus important to prevent excess atmospheric humidity. The most favorable are gently sloping terrains (air mass movement occurs even in the absence of wind), flat lands and the plateaus (air movement occurs at the slightest breeze), less favorable being the depressions and the enclosed lowlands (in rainy regions, cryptogamic diseases attack more strongly, the roots of the walnut grow weaker and trees bear less fruits). Dry air causes loss of water from tissues and soil, dries out the stigmata and hinders pollination [3,4,11,12,17]

The ecological conditions of Gorj County are as follows [19,23,29,34]:

- Climate—very favorable conditions, multi-year average temperature = 10.20 °C, multi-year average precipitation volume = 753 mm, relative air humidity = 72% and existence of areas with Mediterranean climate influences;
- Relief—represented by the Oltenia Subcarpathians and Getic Plateau, composed of the inland depression Tismana-Novaci and the Subcarpathian hills crossed by rivers and streams, creates a favorable climate for the walnut;
- Soils—ranging in density from alluvial to typical podzols, from skeletal to brown forest soils, have a low degree of natural fertility the favorability coefficient of about 2.4 can be enhanced by fertilization and irrigation measures.

In this context, for Gorj County, 3 areas of favorability for walnut cultivation have been delimited (Figure 2) [29,59,60]:

- Very favorable area—located in the inner Subcarpathian depression Tismana—Novaci, on an area of 73,141 ha of agricultural land, with wide possibilities of expanding cultivation, with a Mediterranean-influenced climate, skeletal alluvial soils, weakly podzolic.
- Favorable area—represented by the inner and outer Subcarpathian hills and the Getic Plateau, between Motru and Jiu rivers and between Gilort and Olteţ rivers, with an area of 93,766 ha, with brown forest, normal, eroded, podzolic soils.
- Less favorable area—located in the intracolinary depression Cîlnic—Târgu -Jiu—Câmpu Mare and the rivers' meadows, with an area of 103,766 ha of agricultural land; it is not recommended to establish walnut plantations, since the area is under the influence of cold air currents that move from the mountains to the river valleys, accumulate in the low depression and destroy the fruit buds, and late spring fogs cause crop losses.

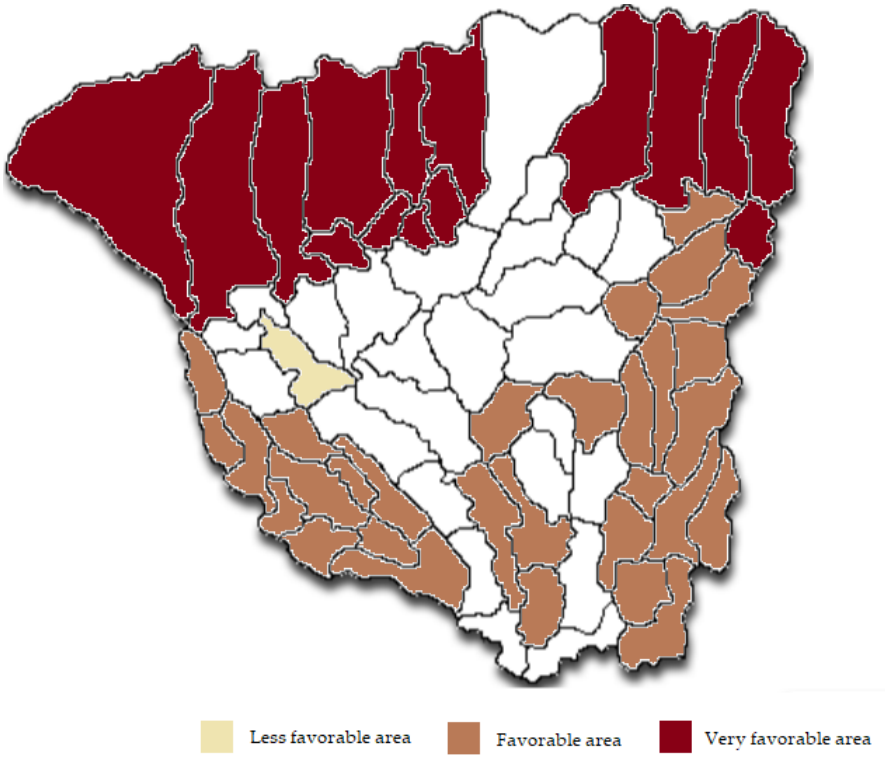

Figure 2. Areas of favorability for walnut cultivation in Gorj County, Romania.

The ecological cultivation of walnut is a success in the pedoclimatic conditions of Gorj County, through the practice of appropriate technological solutions, which implies the elaboration of the design theme that must include: pedological study, evolution of climatic factors over time (negative and positive extremes, relative air humidity, risk of late mists, hailstorms), soil moisture dynamics correlated with the volume of precipitation, groundwater depth, slope (which gives indications on the danger for erosion and landslides), exposure, possibilities for mechanising maintenance and harvesting works, possibility for drip irrigation, varieties (suitable, zoned, with quantitative production potential, qualitatively superior), cost estimates (detailed with mechanical works, materials and labor for the establishment of the plantation), maintenance works (fertilization and phytosanitary treatments specific to an organic culture), harvesting technology, valorization of fruit production (whole, kernel, ground), economic efficiency (plantation profitability), recommendations for by-products valorization (leaves, walnut shells) [29,36,59,60,69,70].

4. Materials and Methods

For the establishment and valorization of a walnut plantation in the conditions of Gorj County, Romania, the pedological and climatic conditions are taken into account, depending on the area of favorability. For the zones of favorability, I and II, intensive and super-intensive cultivation is recommended, with varieties obtained by grafting on approved plant rootstocks, but also with zoned varieties, tested in research fields. This avoids the risk of partial or total loss of production due to very low temperatures (below −25 °C) or to late mists. In this respect, early varieties are subject to the calamitous danger of losing not only that year's production, but also production in the next 2–3 years, by affecting branches aged one or two years. The most favorable soils are those with pH = 6.5–7.6, while those with pH = 8.5 are allowed also, but with the application of amendments. The most favorable sites are those on flat land or land with a slope of up to 10%, allowing mechanized maintenance works [3,4,11,12,28,29,59].

The land intended for the establishment of a walnut plantation must be geographically located in the hilly area of Gorj County, with a low slope configuration, with a terraced appearance, which is a convenient element in the context of walnut cultivation technology, and in a favorable area from the pedoclimatic point of view, in order to meet the recommendation for a natural suitability score of minimum 2.4 and good suitability class for fruit orchards [4,17,18,28,34].

In this respect, resistance to climate and diseases studies on Romanian varieties (Table 1), pedological, suitability and pedoclimatic studies were carried out in the depressional area of Gorj County (Table 2). In order to establish the suitability class for walnut cultivation, the land was classified in the suitability category, on the criteria of limiting factors for production (Table 3).

Table 1. Romanian varieties with terminal fruiting and their main agrobiological characteristics.

Variety Name	Force	Fruit Size (g)	Walunt Kernel (%)	Fats (%)	Protein Substance (%)	Ripening Period Decade/Month	Remarks
Geoagiu 65	average	14	49.5	63.3	19.3	II/9	- resistant to frost, drought and bacteriosis
Jupânești	medium	11	51	67.3	16.3	III/9	- resistant to frost and bacteriosis
Novaci	semivigorous	11.7	47	64.5	16.5	II/9	frost resistant
Șușița	medium	12	50	66.9	19.5	III/9	resistant to drought and bacteriosis
Sibișel 252	medium	12	49.8	68	16.5	II/9	- frost resistant

Table 2. Indicators of the area's soil and climate characteristics, favorable to the cultivation of walnuts.

Indicator	Recommended Values for the Walnut Plantation	The Values Determined in the Hilly Area of Gorj County
Average annual temperatures	8–9 °C	8.5–9 °C
Minimum temperatures	−24−27 °C	−31 °C
Maximum temperatures	35–45 °C	40.6 °C
Number of cold hours (0–7 °C)	600–700	-
Annual precipitation level	500–800 mm/year	750–800
The slope of the land	maximum 10%	flat 3%
Landslides	absent	0
The degree of fragmentation	-	average favorability 3

Table 2. *Cont.*

Indicator	Recommended Values for the Walnut Plantation	The Values Determined in the Hilly Area of Gorj County
The exploitation depth of the root system	1–1.5 m	the structure of the soil allows the development of the root system
Gleization	absent	0
Pseudogleization	absent	0
Texture (0–20 cm)	clayloam	clayloam
Porosity	−10 . . . −20	−20
Ground water level	maximum 2.5–3 m	3.5 m
Excess moisture	absent	0
Floodability	absent	0
ph	6.2–8.5	6.64–6.87
The edaphic volume	101–125%	113
$CaCO_3$ and carbohydrate content	maximum 10%	absent
Reserve humus	60–120 t/ha	90
Fertility level	-	medium

Table 3. Limiting factors for walnut cultivation, determined value and suitability category.

Limiting Factor for Walnut Cultivation	Value Determined	Category of Suitability
soil thickness down to the compact rock	113	I
useful edaphic volume	113	I
degree of salinization	0	I
degree of alkalinization	0	I
horizon depth	175	I
activ $CaCO_3$	absent	I
soil reaction down to 100 cm	6.6	I
Al changeable	absent	I
vertical character	no	I
land slope	3	I
degree of unevenness of the terrain	1	I
damage to the land through surface erosion	1	I
depth erosion	0	I
landslides	absent	I
groundwater depth	3.5	I
volume of non gleized soil	95	I
excess moisture intensity	1	I
volume of non pseudogleized soil	95	I
lateral infiltration on the slope	1	I
overland flooding	0	I
groundwater drainage	2	II

The land suitability for the establishment of the walnut plantation requires a complex, thorough knowledge operation of the growing and fruiting conditions of the walnut and

determination of the degree of favorability conditions for each use. When rating land under natural conditions, each element participates in determining the rating score, with a rating coefficient between 0 and 1, depending on the respective appropriation (totally unfavorable or optimal for walnut). The bonus score is obtained by multiplying the product of the coefficients by 100 (Table 4).

Table 4. Suitability datasheet of walnut cultivation in Gorj county.

Name of the Indicator	Value Determined	Classification Limit	Quality Coefficient for Walnut Cultivation
average annual temperature	8.5	8.1–9.0 °C	1
average annual precipitation	750	701–800 mm	0.9
gleization	0	absent	1
pseudogleization	0	absent	1
salinization and alkalinisation	0	absent	1
texture 0–50 cm	62	clayly-loamy texture	0.9
slope	0.3	3–5%	1
landslide	0	absent	1
groundwater depth	3.5	1.5–2.0 m	1
flooding	0	absent	1
total porosity	+0.5	0–10	1
$CaCO_3$ content	0	absent	1
pH (reaction) (0–20 cm)	6.6	6.5–9.0	1
soil volume	113	101–125%	1
humus reserve	90	61–120 t/ha	0.9
excess moisture	0	absent	1
The product of the suitability coeficients			0.729
Credit rating			73
Quality class			II
Degree of favorability in natural regime			Average favorability Natural favorability 2.84

The stages to be followed and the defining indicators to be taken into account when establishing a walnut plantation are [3,4,11,12,17–19,28,59,70]:

1. Land and surface size selection

For the establishment of walnut cultivation, land with fertile, mechanizable soils with the potential to improve agro-productive properties is recommended. The land intended for walnut plantation must comply with the micro-zoning conditions, related to:

- soil fertility (fertile soils with medium, loamy texture, loamy-sandy lands, medium to deep permeable, pH = 4.7–8.5);
- land slope (gentle slope of 3–6% for easy maintenance and transport of fruits);
- water source (possibilities for drip irrigation, external water sources with water capture possibilities, wells, drillings);
- occurrence and frequency of frosty conditions (area protected from late spring and early winter frosts, sun exposed land, with N-S oriented rows);
- soil moisture and drainage (permeable soils, to avoid waterlogging, groundwater over 2–3 m deep);

- air currents (it is not recommended to plant in narrow valleys with air currents and in areas with late spring frosts).

The size of the orchard depends on the following limiting factors: the size of land and plots suitable for the walnut cultivation in an intensive and super-intensive system; financial sources available for setting up, maintenance and endowment; human resources for the materialization of the project; internal and external sale markets. For Gorj County, an of 7–10 ha is considered optimal, giving the orography of the land.

2. Land preparation for the intensive walnut plantation consists of the following technological works:
   - demarcation of the land allocated for plantation;
   - marking and construction of the protective fence (metal netting and concrete pillars);
   - clearing of woody and herbaceous vegetation (clearing of the land with the help of a tractor equipped with special devices for total removal of roots and transport to special places for storage and destruction by chopping or burning);
   - levelling of the terrain that favors the accumulation of water or hinders the passage of machinery (one slight slope of the land surface allows the natural drainage of water resulting from the melted snow);
   - biological soil test;
   - application of pesticides (fungicides, insecticides with disinfectant effect);
   - soil fertilization (with manure—40–60 t/ha, P_2O_5—250 P kg/ha, K_2O—300 K kg/ha, organic fertilization being necessary for poor soils; a quantity of 45 t manure /ha is recommended for land preparation by land clearing and 15 kg/tree at the planting pit; organic fertilizers are applied after cleaning and levelling, by uniformly spreading them over the entire area and incorporation into soil by ploughing at 20–25 cm depth; P and K are applied throughout the surface, and incorporated by ploughing or disking; the recommended N content from planting to fruiting is 50 g N active substance/sq.m, therefore N fertilizer should be applied in spring, on the worked area, around the tree, of at least 1 sq.m in the year of planting; fertilizers with a slightly alkaline physiological reaction are recommended: nitrocalcar) [64,65];
   - mobilising the soil at 50–60 cm (by unclogging or scarifying—two perpendicular passes, in the autumn before planting or in the spring of the year of planting);
   - light ploughing and levelling (at 30–50 cm, 2–3 months before planting);
   - two-way disking (a few days before planting);
   - parceling and land marking (the choice of the marking pattern depends on the plantation system and on the distances between the trees; consists of marking on the field the places where each tree will be planted, the direction of the rows will be parallel to the long side of the parcel in the N-S direction; for the alignment of the stakes, 1.5–2 m high stakes visible from a distance are used to draw the lines framing the field in a rectangle, with a multiple of 8 × 5 m; marking in the shape of a rectangle is specific to walnut cultivation and ensures an optimal space for tree growth evenly distributed among all the trees in the orchard; the rows are placed at a distance of 4 m from the fence to ensure movement around the fence and to avoid branches growing outside it; the length of the rows is oriented in the north-south direction, to ensure a large amount of light throughout the day and to avoid the phenomenon of plantation shading).
3. The choice of varieties for planting takes into account the selection criteria: origin of planting material, fruiting time, fruit size, kernel yield, fruit ripening period, diseases and frost resistance. Given that the trees grown on their own roots bear fruit after 10–15 years, the Juglans regia grafted walnuts at year 6–8 after planting and Juglans nigra at 5–6 years, one criterion for selecting varieties is the age at which the first economically efficient harvests appear. Grafted walnuts also produce better quality fruit with higher commercial and food value; from the walnuts grown from seeds a

maximum of 20% quality fruit can be collected. For these reasons, it is recommended that the walnut plantation be planted with genetically certified grafted trees, the recommended varieties for modern plantations being small trees, side-fruiting, early, homogenous, productive, and resistant to the main walnut diseases such as bacteriosis and anthracnose [4,11,19,23,28,71]. The nuts of the new varieties have smooth and thin endocarp, strong and welded valves, the kernel fills all the interior and is easily extracted completely or in halves and represents 40% of the fruit weight (Figure 3).

Figure 3. Walnut planting material.

Walnut varieties are classified into [4,19,23]:

- standard (fruits on long, thin branches, presents long, thick branches and short internodes);
- spur (with early fruiting and short thin or short thick branches);
- semi spur (fruiting on medium-sized branches with short internodes).

There are three possible ways of using the varieties:

- only Romanian varieties (early varieties come into bearing in the 6th–7th year or 8–10 years from planting, but have the advantage that they are tested over time, in terms of production constancy and resistance to climate and diseases) (Table 1);
- only foreign varieties (of Hungarian and French origin, which have the property of bearing fruit much faster, in the 3rd–5th year, but are much less adaptable to the Romanian conditions and show lower resistance to diseases and cold; in years 4–5, these varieties lose their fruit buds and the investment may be compromised);
- local and foreign varieties.

Certified organic (with blue certificate) planting material will be used, with local or foreign terminal fruiting varieties being recommended for Romanian conditions, as they are more resistant to low winter temperatures than the lateral fruiting varieties and have the best quality fruit, being competitive on the international market. The choice of fruit material must take into account flowering, pollination and fertilization characteristics of the walnut tree. By using varieties with different flowering and fruiting times, optimal pollination in the orchard and economic efficiency from years 4–6 after planting is ensured. Nowadays, walnut cultivation also recommends varieties with lateral fruiting, which, in addition to the terminal fruiting, double or triple the nuts production [72,73].

To ensure maximum pollination effect between varieties, the following rules are recommended [3,19,23]:

- the varieties show pollination compatibility and have the same flowering period;
- the distance between the basic variety and the pollinating variety is not too large;
- pollination is done with the help of bees and wind, for a good pollination at least two bee families/ha are needed; to protect the bees during the flowering period, it is recommended not to spray with insecticides;
- placing hives for pollination is made in the immediate vicinity of the orchard or right in the middle of it, mandatory at the beginning of flowering.

Under Romanian conditions, rootstocks from Juglans regia (selections) perform well when grafted with native varieties, as rootstocks are tolerant to Cherry Leavroll virus (CLRV).

4. Planting of walnut seedling material and planting density [11,12,17,28,59,60]
   - for intensive plantations, the planting distance = 8 m between rows and 6 m per row between trees, respectively, a density of 208 plants/ha; for super-intensive plantations, planting distance = 7 m between rows and 5 m between trees, respectively, 285 plants/ha; it provides a feeding space of 48 m^2 for intensive systems and 35 m^2 for super-intensive systems
   - the planting actions take place between 15 October until the first frost or as early as possible in the spring (after soil defrosting and drying, when the soil has high humidity)
   - the pits of 50 × 50 × 60 cm size are dug manually or mechanically, on the cleared and prepared land, shortly before planting or on the day of planting, so as not to lose the moisture accumulated in the soil; after digging the pits, add 20–30 kg of well-fermented manure and drag 2/3 from the soil into the planting pit
   - the roots are placed in a mixture of 3 parts yellow soil + 2 parts fresh manure + water, the mud layer is intended to provide more moisture around the root system and ensure better adhesion of soil particles around the root
   - the trees are planted with the grafting point at the ground level and are watered with 15–20 L water each (Figure 4).

Figure 4. Planting walnuts.

5. Designing the crown of trees [3,11,12,28,34,59,60]

Walnut crown construction is based on the pruning principles and rules applied to trees with large volume crowns (in the form of an improved vase or delayed vase and the Leader pyramid with 5–7 frames) (Figure 5).

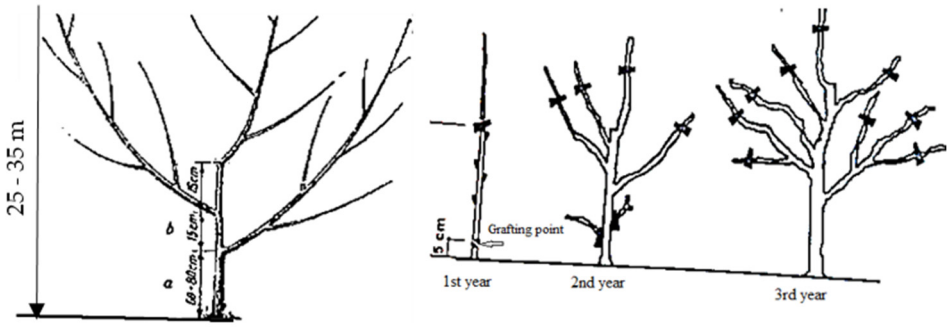

Figure 5. Crown of improved vessel type and Leader type with 5–7 frames.

Cuttings for maintenance and fruiting are based on the removal of competing branches located in poor positions impeding light penetrating into the crown; reduction cuttings are made in the aged branches to stimulate the growth of new branches with higher productive potential. Walnut is a species that is sensitive to pruning, hence pruning during the dormant

period is only done when the danger of negative temperatures decreases, with the best results being obtained when pruning is done in late March—early April.

6. Walnut plantation maintenance works [3,11,17,18,71,74,75]
    - Grass planting—for an organic crop production, work will be carried out to eliminate the impact of herbicides. Between the rows, a grass planting system is chosen, with spotted mowing, and the resulting green mass is left on the ground as compost and green manure. This action maintains constant soil moisture by reducing evapotranspiration and will favor the development of micro-organisms with the role of decomposition of the plant mass and nutrients and humus formation needed by plants. Perennial herbs (Lolium) and annual leguminous plants (peas, lentils, vetches) or annual cereals (rye, oats, triticale) are used. Autumn peas incorporated into the soil in spring, provide 120 kg nitrogen (Figure 6).
    - Combating late fogs and frosts is achieved by fumigation, slow-burning materials produce a lot of smoke, without flame (semi-dry dung, peat, litter, dried weeds, vines, rubber debris (Figure 7)
    - Phytosanitary treatments—for organic walnut cultivation, specific treatments for diseases and pests are necessary, without using toxic chemical compounds [12,34]. Even if the walnut has few diseases and pests, the phytosanitary state must be ensured, to avoid quantitative and qualitative production losses. The methods are applied before and after fruiting to control viruses, bacteria, parasitic fungi, insects, spiders, worms, rodents, birds or by applying mechanical and cultural hygiene measures during the winter period.

Figure 6. Partial grass planting on a walnut plantation.

Figure 7. Application of fumigation to combat haze and frosts.

Preventive measures include: collecting diseased leaves and branches and storing them in pits for fermentation and treatment with lime and $CuSO_4$; placing pheromone traps for various pests; destroying fruit affected by diseases and pests; carrying out dormant period treatments with $CuSO_4$ 3–5% solution; manual scraping of moss-affected trunks and annual

tilling with a solution of $CuSO_4$ and lime; digging the soil around the stems and ploughing the entire blacktop area (in early autumn to remove pests and to allow air and water to easily penetrate the roots, contributing to nutrient extraction and treatment processes).

Curative methods involve the use of products permitted in organic farming: 0.5–5% Bordeaux juice (depending on the growth stage), extracts of certain plants containing toxins (wormwood) [36,65].

Walnut diseases are: bacterial blight Xanthomonas Campestris Pierce Dye sin. *Xantomonas juglandis*; antagnosis *Gnomonia juglandis* Trav; bacterial cancer, *Pseudomonas syringae* van Hall; *Phytophtora ciannamomi* Rands; galicolous root cancer; black line disease; *Melanconis juglandis* Groves; blackening and drying of branches, *Melanconium juglandinum* Kuntze (Figure 8). The walnut pests are: walnut worm, red spider, turtle lice, bud beetle [76,77] (Figure 9).

Figure 8. Walnut diseases.

Figure 9. Walnut pests.

- Fertilization involves only the application of organic, mineral or green fertilizers (which ensure normal or vigorous shoot growth, promote the formation of a large number of fruiting shoots for the following year's production and increase the volume and weight of the fruit, therefore must contain the main and secondary macronutrients N, P, K, Mg and the micro-nutrients Fe, Cu, B, Al, Mn): animal manure, poultry manure and compost (fermented, from farms where no chemical disinfectants were used, applied in autumn, in the amount of 30–40 t/ha, on the area under the crown projection, administered at the planting year and later at the 3rd and 4th year), green manures from legumes (peas, peas, lupins, lentils), cereals (rye, triticale, oats, with incorporation under the furrow in the planting or seeding phase), calcareous additions (on acid soils, but without nitrogen content), organic foliar fertilizers (based on algae and amino acids), copper sulphate (used during the dormant and growing season), organic products and by-products of vegetal and animal nature [3,11,12,28,36].
- irrigation—the super-intensive plantation system requires the provision of supplemental quantities of water, depending on climatic conditions, by the following watering methods [78–81]:
    - through furrows
    - through sprinkling (distributing water in plantations using systems and devices operating under pressure)
    - through dripping (localized) (slow delivery of water to the active root zone of the trees; watering pipes are placed along the rows of trees, fixed at ground

level, or at various heights, on the trunk of the trees or on espaliers at the bottom wire) (Figure 10)

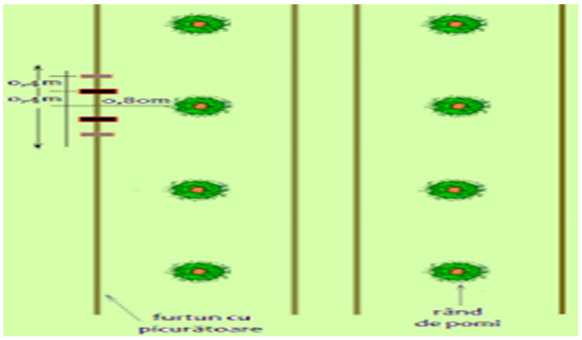

Figure 10. Drip irrigation of walnuts.

7. Fruit harvesting—the fruits are harvested in baskets, crates, buckets, sacks, using ladders and platforms, manually or mechanically, with controlled shaking de-vices and equipment (a vibrating equipment attached to a tractor, which applied to the trunk of the tree for 5 min of vibration leads to the fall of the nuts; another machine sweeps the fallen nuts and collects them in a line in between the rows; the pick-up equipment works on flat ground, without grassy debris, after its passage comes an exhauster attached to a tractor which absorbs the nuts and puts them in a trailer); the nuts are then put in a water bath and in a mesocarp removing machine for 2–4 days; they are dried in ventilation plants; they are stored in natural conditions, in ventilated sheds 6–12 months (Figure 11) [3,11,28,82–84]

Figure 11. Equipment for harvesting nuts.

Walnuts come into bearing fruits in year 3–4 after planting, yielding 200–300 kg/ha, but after year 7–8 after planting, walnut in shell production reaches 3–5 t/ha. Fruit yield is the result of several technological factors, but the correlation between climatic indicators and the growing season is essential. The occurrence of disruptive climatic factors during the flowering, pollination or fruiting periods, leads to production losses.

In order to highlight the sustainability and the economic efficiency of setting up an organic walnut plantation in Romania, in Gorj county, an economic analysis was carried out, considering that the costs of setting up a walnut plantation include labor, raw materials, materials, machinery, transport [85–87].

Total value of the investment = Setting-up costs + Orchard maintenance costs up to fruition.

Expenditure on basic agro-technical work for the establishment of a walnut plantation with an area of 1 ha are presented in Table 2. Expenditure on the establishment of the organic walnut plantation in intensive system IS and super-intensive system SIS are presented in Table 3. Material costs for the establishment of the organic walnut plantation in intensive and super-intensive cultivation are presented in Table 4. Costs for the maintenance of the organic walnut plantation in intensive and super-intensive systems are presented in Table 5.

Costs for the maintenance of the walnut plantation in intensive and super-intensive years II-III and IV are presented in Table 6.

Table 5. Expenditure on basic agro-technical work for the establishment of a walnut plantation (1 ha area).

Name of the Agro-Technical Work	Price (Euro)
Scarifying	184
Land leveling	82
Ploughing 25–27 cm	122
Two-ways tilling	122
TOTAL	510

Table 6. Expenditure on the establishment of organic walnut cultivation in intensive IS and supe-intensive systems SIS.

Normativ Position/ Standard/Category of Work	Name of the Work	UM	Materials (Euro)		Labour (Euro)		Equipment (Euro)		TOTAL	
			IS	SIS	IS	SIS	IS	SIS	IS	SIS
1151 Order 801/386/III	Land marking for classic plantations	ha/ pcs.	42.4	58.4	7.4	10.2	-	-	49.8	68.6
1161 Order 801/390/III	Digging pits for planting trees 40 × 40 × 40 cm	pcs.	9.2	12.7	151.8	157.6	-	-	161	170.3
1165 Order 801/3892/I	Distribution of the pickets to pits	pcs.	84.9	116.3	46.5	63.8	-	-	131.4	180
	Tree transport	km	-	-	-	-	21.4	21.4	21.4	21.4
1773 III	Ditch making for layering 50 × 50 cm	ml	-	-	1.6	2	-	-	1.6	2
1775 III	Layered trees in ditches	pcs.	-	-	3.9	5.3	-	-	3.9	5.3
1168 I	Mud making	thousand pcs.	0.8	1.2	3.5	4.7	-	-	4.3	5.9
1169 I	Root trimming and mudding	thousand pcs.	0.8	0.8	3.5	0.8	-	-	4.3	1.6
1171 Order 801/395/I	Manually tree allocation to pits	Thou-sand pcs.	4245	5816.3	3.7	5.1	-	-	4248.7	5821.4
1952 II	Manure transportation	t h/day	171.4	196	6.1	8.4	12.5	17	190	221.4
1191 S.v.c.2.b. II	Manure spreading (20 kg/tree)	t	-	-	28.4	38.8	-	-	28.4	38.8
1174 Order 801/396 IV	Tree planting complete work	pcs.	-	-	54.5	74.7	-	-	54.5	74.7
1176 Order 801/399 I	Watering trees at the pit	pcs. m^3	0.8	1.22	11.6	16	12.5	16.7	24.9	33.92
1175 Order 801/397 I	Tying trees to stakes	pcs.	21	28.1	9.5	12.9	1.9	4.7	32.4	45.6
	Crown formation at planting	pcs.	34.7	37.8	4.3	5.9	-	-	39	43.7
1236 I	Manual stem varnishing	kg pcs.	20.4	28.1	3.5	4.7	3.5	4.7	27.4	37.5
	Grass planting between rows		306	306	-	-	31	30.6	337	336.6
	TOTAL		4937.4	6602.9	339.8	410.9	82.8	95.1	5360	7108.8
	%		92.1	92.9	6.34	5.78	1.54	1.33	100	100

Expenditure is based on the average rates charged by most service providers for mechanical work. For manual works, the tariffs are based on the Technical Working Standards for manual works elaborated by the Ministry of Agriculture, Romania, correlated with the provisions of the Framework Law no.153/2017 Annex VIII, Chap.II, let.G, Agriculture. Average market prices were taken into account for material expenditure [88].

The potential fruit yield (nuts) and the estimated value depending on the age of the plantation and the cropping system (kg/ha) is calculated for an average of 27 years of cultivation, taking into account that after year 10, a minimum of 25 kg fruit/plant is obtained (Table 7).

Table 7. Material costs for the establishment of organic walnut cultivation in intensive (IS) and super-intensive systems (SIS).

Material Name	UM	Amount		Value (Euro)	
		SI	SSI	SI	SSI
Grafted walnut planting material	Pcs.	208	285	4245	5821.4
Wood pickets	Pcs.	208	285	42.5	58,2
Manure	To.	4.2	5	171.4	196
Wood stakes	Pcs.	208	285	84.9	116
Foil for tree binding	Kg.	2	3	20.4	31
Pliers	Pcs.	5	5	20.4	20.4
Hoes	Pcs.	5	5	20.4	20.4
Tree scissors	Pcs.	3	3	20.4	20.4
Lime	Kg.	5	7	10.2	14.2
Water for watering				301.4	305
TOTAL				4937	6603

5. Results and Discussion

Analyzing the data in the table with the pedoclimatic characteristics of the county, it can be seen that all the indicators fall within the recommended optimum values for cultivation of walnut plantations, with the exception of the fertility level, where fertilization actions are necessary at all stages of the establishment and exploitation of the plantation [3,11,17,28,59].

The classification of the land in the suitability category was based on the limiting factors for walnut cultivation, taking into account the values determined for the physical and chemical soil quality indicators [3,34].

In the suitability class II are soils with good permeability and low limitations, the danger of degradation being prevented by simple amelioration measures, the only restriction being imposed by moderate groundwater drainage, due to the clayey-loamy texture at the base of the soil profile.

- Natural suitability score for walnut cultivation = 2.84
- Strengthened favourability score = 3.29

Credit ratings decrease due to climatic conditions without imposing severe limitations. The luteous texture imposes moderate limitations, due to the defective aerohydric regime up to 50–60 cm, requiring scarification or subsoiling. Moderate humus content, maximum 120 t/ha, can be compensated by fermented manure.

Organic walnut plantation, under conditions of exploitation in favorable areas and of production valorization according to the supply/demand ratio, is economically efficient. For a super-intensive cultivation system, the costs of purchasing and planting the seedlings are the most significant, followed by the costs of fencing the land and preparing and fertilizing the land. For the costs of maintaining the plantation until it comes to bear fruits,

labor costs account for the largest share, followed by raw materials and mechanized costs. After fruition, labor costs account for the largest share of operating expenditure, followed by raw materials, materials and mechanized work (Tables 5–9).

Table 8. Expenditure for the maintenance of organic walnut cultivation in intensive system (IS) and super-intensive systems (SIS).

Normativ Position	Name of the Work	Costs (Euro/ha)						Total (Euro)	
		Materials		Labour		Equipment			
		SI	SSI	SI	SSI	SI	SSI	SI	SSI
1162	Digging pits for completed goals 10%	-	-	15.3	20.4	-	-	15.3	20.4
1173	Trees planted, complete work including watering	428.5	592	5.5	7.6	-	-	434	599
1175	Tying the trees to the stakes	1.02	1.4	1.02	1.4	-	-	2.04	2.8
1236	Whitening of stems	2.04	2.5	0.4	0.6	-	-	2.44	3.06
1224	Harrowed 3 times with a hoe of $\frac{1}{4}$ of the surface	-	-	104	104	-	-	104	104
1757	Prepared solution for spraying—5 treatments	318.5	347	2.5	3.06	-	-	321	350
1725	Sprayed the trees with vermorel—5 treatments	-	-	101	106	-	-	101	106
1261	Crown forming cuts	-	-	4.9	6.1	-	-	4.9	6.1
221	Cut the grass per interval	-	-	-	-	20.4	20.4	20.4	20.4
N.L.	Drip irrigation 4 waterings × 30 L/tree	43	59	234	327	102	140	379	526
	TOTAL	793	1002	468	576	122.4	160.4	1.384	1.738

Table 9. Expenditure for the maintenance of walnut cultivation in intensive and super-intensive systems years 2, 3 and 4.

Normativ Position	Name of the Work	Expenses (Euro/ha/Year)					
		Materials		Labour		Equipment	
		IS	SIS	IS	SIS	IS	SIS
1175	Tying trees to stakes	5.3	7.6	4.08	5.1	-	-
1236	Stem varnishing	8.7	9.6	21.4	24.5		
1224	3 times hoeing on $\frac{1}{4}$ of the surface	-	-	104	104	-	-
1757	Solution preparation for spraying—5 treatments	643	882	102	122	-	-
1725	Spraying trees with pump	-	-	122	168	-	-
1261	Crown formation cuttings	-	-	8.1	10.2	-	-
N.L.	Dripping irrigation 4 waterings × 30 L/tree	71	92	265	318	61.2	61.2
221	Mechanical grass mowing 3 times	-	-	-	-	92	92
	TOTAL	728	991	627	752	153	153
	TOTAL SI	1508 euro					
	TOTAL SSI	1896 euro					

Expenditure on the establishment and maintenance of the walnut plantation in the intensive and super-intensive systems (year 1 to 4 until fruiting), for an area of 1 ha, shows the share of expenditure in the total investment as follows: material expenditure (50.8% and 56.4%, respectively), labor expenditure (11.5% for both systems), design expenditure and pedological study (15% for both systems).

Revenues were calculated on the basis of a multiannual average production of 3150 kg/ha fruits in the intensive system and 4100 kg/ha fruits in the super-intensive system, valued

at 1.6 euro/kg nuts. The average annual income is 5000 euro/ha in the intensive system and 6500 euro/ha in the super-intensive system. Thus, the income achieved ensures a net profit of 1638 euro/ha in the case of intensive plantations and 2503 euro/ha in the case of super-intensive plantations, to which is added the subsidy from the Romanian Agency for Payments and Intervention in Agriculture for organic farming, amounting 480 euro/ha (Table 10).

Table 10. Potential production of fruits (nuts in shell) and estimated value by plantation age and cropping system (kg/ha).

Normativ Position	Name of the Work	Expenses (Euro/ha/Year)					
		Materials		Labour		Equipment	
		SI	SSI	SI	SSI	SI	SSI
1175	Tying the trees to the stakes	5.3	7.6	4.08	5.1	-	-
1236	Whitening of stems	8.7	9.6	21.4	24.5		
1224	Harrowed 3 times with a hoe of $\frac{1}{4}$ of the surface	-	-	104	104	-	-
1757	Prepared solution for spraying—5 treatments	643	882	102	122	-	-
1725	Sprayed trees with vermorel	-	-	122	168	-	-
1261	Crown forming cuts	-	-	8.1	10.2	-	-
N.L.	Drip irrigation 4 waterings × 30 L/tree	71	92	265	318	61.2	61.2
221	Cut the grass mechanically 3 times	-	-	-	-	92	92
	TOTAL	728	991	627	752	153	153
	TOTAL SI	1508 euro					
	TOTAL SSI	1896 euro					

Analyzing the data in Table 11, it can be seen that the profit rate of 54% and 71%, respectively, provides a payback period of 7.7 years for the intensive plantation and 6.0 years for the super-intensive plantation. The economic return on investment shows that for every 1 euro invested, 310 euro is obtained in the case of intensive cultivation and 395 euro in the case of super-intensive cultivation over the entire period of exploitation, with a total profit of 39,312 euros and 60,072 euros, respectively.

Table 11. Efficiency indicators for a walnut plantation in intensive system (208 trees/ha) and supe-intensive (285 trees/ha), for a cultivated area of 1 ha [89–91].

Specification	U.M.	Cultivation System	
		Intensive	Super-Intensive
Density	No trees/ha	208	285
Effective operation life (E.o.l.)	years	30	30
Service life (S.l.)	years	24	24
Total investment value (T.i.), of which:	euro/%	12,700/100	15,194/100
Design and technical assistance	euro/%	1184/9.3	1184/7.8
Pedological study	euro/%	1225/9.6	1225/8.0
Land preparation	euro/%	510/4.0	510/3.4
Fencing	euro/%	1530/12	1531/10.0
Material expenses	euro/%	6458/50.8	8596/56.6
Labour costs	euro/%	1435/11.3	1739/11.4

Table 11. *Cont.*

Specification	U.M.	Cultivation System	
		Intensive	Super-Intensive
Mechanical expenses	euro/%	358/2.8	409/2.7
Annual expenses (A.e.), of which:	euro	3051.5	3520
Annual exploitation (A.Expl.)	euro	2102	2398
Direct and unexpected costs 10%	euro	210.2	239.8
Indirect costs 10%	euro	210.2	239.8
Annual depreciation rate A.d. = T.i./S.l.	euro	529	642
Annual direct expenses D.e. = A.d. + A.Expl.	euro	2631	3040
Average production (P.)	kg/ha	3150	4100
Selling price (S.p.)	euro/kg	1.6	1.6
Value of annual production V = P. × S.p.	euro/an	5000	6500
Gross annual profit G.A.P. = V − S.p.	euro	1950	2980
Income taxes I = G.A.P. × 16%	euro	312	477
Net income N.I. = G.A.P. − I	euro	1638	2503
Annual profit rate P.r. = N.I./A.e. × 100	%	54	71
Return on investment T = T.i./N.I.	years	7.7	6.0
Total profit on the exploatation lifetime P = N.i. × S.ș.	euro	39,312	60,072
Economic return on investment ROI = P/T.i. × 100	%	310	395

According to the analysis of the efficiency indicators, it can be observed that the establishment of an organic walnut plantation, on an area of 1 ha, in Gorj County, Romania, is a sustainable, appropriate and worthwhile investment, in terms of land use, agricultural potential, environmental protection and social and economic impact. These economic indicators place intensive and super-intensive organic walnut cultivation in the category of the plantations with a high economic yield if grown in favorable and very favorable areas of Gorj County, Romania.

6. Conclusions

The walnut (Juglans regia) is a fruit species in which all countries with a tradition in creating varieties and applying technologies to increase the quality and quantity of production have shown interest over time, being a source for food, skin care and phytotherapeutic products, raw material in various industrial branches, used for biomass or decorative objects.

In Romania, one of the largest walnut-producing countries in the world, walnut is a reference species, on an upward trend and with great prospects, because the establishment, cultivation and exploitation of a walnut plantation, in an organized system, contributes to the sustainable development of the area.

Although it grows slowly and comes to bear fruits relatively late, walnut has the following advantages: is suitable to organic cultivation, without the use of chemical fertilizers and phytosanitary products; it has an ecological impact, due to its atmospheric purification properties; it supports investments for the restoration of the fruit heritage; by applying new strategies for the implementation of European and national agricultural policies, it contributes to the development of new ways of exploiting the production obtained, by processing the fruits and other vegetative organs of the plant, with significant profits.

The fruit (walnut kernels) has special qualitative properties and can be used in fresh, dried or in processed form (walnut oil), with multiple health benefits for the human body.

The requirements for cultivation are differentiated according to the environmental factors, the characteristics of the varieties, cultivation systems and technologies. Under Romanian conditions, walnuts grown in an organized technological system are restricted by geographical factors, relief, soil, humidity and temperature, and have greater requirements in terms of heat, light, humidity, soil types and nutrients, which are limiting factors in their expansion.

For the establishment and exploitation of a walnut plantation in the conditions of Gorj County, Romania, pedological, suitability and pedoclimatic studies were carried out in the depressional area of Gorj County and it was demonstrated that the pedoclimatic indicators fall within the optimal values recommended for the establishment of a walnut plantation; the land fell within the category of suitability on the criterion of limiting production factors.

In order to highlight the sustainability and economic efficiency of setting up an organic walnut plantation in Romania, Gorj county, in intensive and super-intensive systems, an economic analysis was carried out, taking into account that the expenses related to the establishment and maintenance of a walnut plantation up to 3rd–4th year, including expenses related to agro-technical works, labor, raw materials, equipment, transport.

The potential fruits (nuts) yield and the estimated value depending on the age of the plantation and cropping system (kg/ha) are calculated for an average of 27 years of cultivation, considering that after year 10, a minimum of 25 kg fruit/plant is obtained.

According to the analysis of the efficiency indicators, it can be observed that the establishment of an organic walnut plantation on an area of 1 ha in Gorj county, Romania, is a sustainable investment, as the organic walnut plantation in intensive and super-intensive systems is classified as a plantation with a high economic yield, if it is grown in favorable and very favorable areas and if the appropriate technological systems are used.

The theme can be developed through studies and research on approval of new varieties, adapted to the Romania soil and climate conditions, through development of modern technologies for the establishment and maintenance of a walnut plantation, through identification of new chemical compounds from the vegetative organs, including applications in medicine. Research on walnut cultivation will also be extended to the possibilities of walnut cultivation in other areas of Romania, by adapting to the respective soil and climate conditions, as well as to the establishment and cultivation of walnut and hazelnut intercrops.

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