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BIOLOGICAL PECULIARITIES AND QUALITY OF PHYTOMASS FROM SOME *Salix* L. AND *Populus* L. SPECIES

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Abstract

The rapid development of global bioenergy makes it necessary to find and develop fundamentally new approaches to forest management. Promising plants are species and varieties of the genera Salix L. and Populus L., which are characterized by fast rates of biomass growth. Research has established that the annual growth of species and varieties of the genus Salix L. is 80-145 cm, and that of the genus Populus L. is 120-165 cm. The Salix viminalis phytomass is characterized by 3.53% ash, 44.9% cellulose, 24.7% hemicellulose, 9.1% acid detergent lignin, 50.22% C, 6.00% H, 0.89% N, 0.07% S, 0.05% Cl, 19.77 MJ/kg HHV and 18.46 MJ/kg LHV. The Populus alba phytomass contained 2.82% ash, 50.6 % cellulose, 19.1% hemicellulose, 7.3% acid detergent lignin, 47.83% C, 5.98% H, 0.80% N, 0.16% S, 0.04% Cl, 19.22 MJ/kg HHV and 17.91 MJ/kg LHV. The estimated theoretical ethanol yield from cell wall carbohydrates averaged 510.4 L/t in Salix viminalis substrate and 505.4 L/t in Populus alba substrate, as compared with 476.3 L/t in pruning residues substrate. The creation of short-rotation plantations of Salix L. and Populus L. will make it possible to reduce resource pressure on other categories of forests, increase the forest cover of territories and the productivity of plantations, shorten the time of growing wood with the possibility of its further use for energy purposes.

***Key words**: biological peculiarities, chemical properties, energy properties, phytomass, Populus, Salix, theoretical ethanol potential.*

INTRODUCTION

Biomass is a versatile raw material that can be used for production of heat, power, transport fuels, and bioproducts. The use of plant biomass as an energy carrier is vital due to the zero balance of the carbon cycle (C) in nature. It plays a critical role in reducing carbon dioxide (CO_2) emissions and creates an alternative to fossil fuels as a renewable energy source. The use of biofuels must benefit the environment regarding CO_2 emissions and other components of exhaust gases (Kraszkiewicz et al., 2022).

The problem of developing energy-saving technologies and finding alternative sources of renewable fuels is more acute than ever before for the global community. Despite this, the development and use of solid biofuels production in Ukraine and Moldova is constrained and lags behind both the country's domestic needs and the global dynamics of its development. Every year Ukraine consumes about 200 million tons of fuel and energy resources, covering its needs by only 53%. The UN program stipulates that the share of renewable energy sources in the global fuel and energy balance in 2050 may reach 50%, and according to the World Energy Council, it will reach 80-90% by the end of this century (Energy Strategy, 2011; 2013; Geletukha et al., 2015).

Among all fuels, biomass ranks 4th in the world and accounts for 14% of total primary energy consumption in the world. The largest share of solid biofuels in total energy consumption is in Sweden (Geletukha et al., 2015; 2016). In Ukraine, the share of electricity generated from renewable energy sources amounted to 14.6% or 13.9 GW of capacity in 6 months of 2021, including 230 MW of bioenergy (Kuz'min, 2021).

Today, there are several dozen fast-growing plants that can be grown for plant biomass. The most promising among them are varieties of the genera *Eucalyptus* L'Hér., *Populus* L., *Salix* L., *Robinia* L., *Miscanthus* Anderss., *Zea* L., *Saccharum* L., etc. The collected biomass is used to produce heat and electricity, and can also serve as a raw material for the production of solid biofuels, such as fuel granules, briquettes, and pellets.

Of all the energy crops in the world, it is the varieties of the genus *Salix* and *Populus* L. that are currently used as the main energy crop for solid fuel production. The first energy variety of the *Salix* genus was registered in the Netherlands in 1968, and today more than 230 *Salix* varieties are registered worldwide (Roik et al., 2015). Over the past 10 years, the United States and Poland, as well as Argentina and Romania, have been leading the way in registering new varieties (Lawrence et al., 2015; Roik et al., 2015). In Sweden, the Netherlands, and Germany, most of the energy crop varieties of *Salix* were registered in the 1990s. In Europe, where about 10 thousand crossed plants are produced annually, the breeding of energy crops of the *Salix* genus began in 1987. The period for developing a new variety is 10 years. Currently, there are 24 varieties authorized by EU standards. Every year 1-2 new varieties appear in the world (Holland Plant Ukraine, URL: http://hopu.com.ua/shvedska-energetychna-verba/)

Countries such as Sweden, England, Ireland, Poland, and Denmark have experience in growing *Salix* varieties. In Italy, Germany, Argentina, and Poland, the creation of special plantations of fast-growing *Salix* and *Populus* varieties is widely practiced. In Northern India, plantations of fast-growing species of *Populus* and *Eucalyptus* occupy 50-60 thousand hectares, where about 3.7 million tons of wood are harvested annually. In Europe, large areas are occupied by *Salix* species in Sweden - 18-20 thousand hectares, in Poland - more than 6 thousand (Roik et al., 2015). In Ukraine, the Swedish Energy Willow program has also been operating since 2006. Plantations of *Salix* energy varieties have been planted in Rivne, Volyn, Lviv, Ivano-Frankivsk, Ternopil, Vinnytsia, and Kyiv regions (CMU's Resolution No. 902-p of 01.10.2104 "On the National Renewable Energy Action Plan until 2020" http://zakon4.rada.gov.ua/laws/show/902-2014-%D1%80).

The creation of energy plantations from varieties of the genus *Populus* is being developed in detail in the conditions of Kyiv Polissya and Kharkiv region (H.M. Vysotsky UkrNDILGA) (Vysots'ka, 2014; Fuchylo et al., 2011; Khivrych & Mel'nychuk 2016; Kunts'o & Humentyk, 2013; Ishchuk, 2014; 2015). The phytomass of willows in Kyiv Polissia was estimated by Holiaka et al. (2018).

There are about 5 million degraded lands in Ukraine where energy crops can be successfully grown. However, today the area under energy crops is only about 7,000 hectares. According to experts, energy crops grown on 4 million hectares could replace 20 billion cubic meters of natural gas annually (Kuz'min, 2021). However, despite the large amount of unused non-agricultural land in Ukraine, there are still few industrial energy plantations. In our opinion, reserves of energy crops should be sought among species of local flora that grow rapidly in the soil and climatic conditions of Ukraine and Moldova, given the increasing continentality and aridization of the climate. Therefore, the issue of establishing short-rotation plantations of *Salix* and *Populus* L. on degraded lands in Ukraine and Moldova is topical.

MATERIALS AND METHODS

The objective of the paper is to analyze the taxonomic composition, chorology, energy properties, and resource base of representatives of the *Salicaceae* Mirbel. family in Ukraine and Moldova and, based on the study of annual shoot growth and energy value of phytomass, to identify promising species and varieties for energy plantations.

The material for the work was based on the comprehensive results of the analysis of the chorology and resource base of autochthonous species and hybrid varieties of *Salix* and *Populus* in Ukraine and Moldova. In situ studies of shoot growth of *Salix* and *Populus* species were conducted at the biostation of the Bila Tserkva National Agrarian University by linear measurements of shoot length of willows and poplars every 10 days during June - August (Molchanov & Smyrnov, 1967). Phytomass was analyzed in the laboratory of energy crops of the National Botanical Garden (Institute) named after Alexander Chobotar.

The regulatory framework for energy crops of *Salix* and *Populus* species and cultivars in Ukraine is provided by the Laws of Ukraine "On Alternative Energy Sources" (2008), "On Alternative Fuels" (2009), and "On Seeds and Planting Material" (2010).

As energy biomass the *Salix viminalis* and *Populus alba* phytomass were harvested manually in February, apple tree pruning residues was used as control variant. The phytomass were chopped into chaff using a stationary chopping unit, milled in a beater mill equipped with a sieve with diameter of holes of 6 mm. To perform the analyses of the elemental chemical and content of cell walls, the biomass samples were dried in an oven at 85 °C and then milled (<1 mm) and homogenized. After that, the total carbon (C), hydrogen (H), nitrogen (N) and sulphur (S) amounts were determined by dry combustion in a Vario Macro CHNS analyzer, according to standard protocols. The some physical and mechanical properties of dry biomass were determined according to the standards: the moisture content of the plant material was determined by SM EN ISO 18134 in an automatic hot air oven MEMMERT100-800; the content of ash was determined at 550ºC in a muffle furnace HT40AL according to SM EN ISO 18122; the automatic calorimeter LAGET MS-10A with accessories was used for the determination of the calorific value, according to SM EN ISO 18125.

To determine the cell wall components in the dry mass of tested species, the amounts of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were assessed using the near infrared spectroscopy (NIRS) technique PERTEN DA 7200 at the Research-Development Institute for Grassland Brasov, Romania. The amount of cellulose was calculated as ADF minus ADL and hemicelluloses - NDF minus ADF. The Theoretical Ethanol Potential (TEP) was calculated according to the equations of Goff et al., 2010 based on conversion of hexose (H) and pentose (P):

$$H = [\%\ Cel+(\%\ HC \times 0.07)] \times 172.82$$

$$P = [\%\ HC \times 0.93] \times 176.87$$

$$TEP = [H + P] \times 4.17$$

RESULTS AND DISCUSSIONS

Among the species diversity, the willows of the plain part of Ukraine, which include 16 taxa, are promising for energy plantations. *S. alba* L., *S. pentandra* L., *S. fragilis* L., *S. viminalis* L., *S. acutifolia Willd.*, *S. cinerea* L., *S. purpurea* L., *S. triandra* L., *S. caprea* L., *S. rosmarinifolia* L., *S. aurita* L. However, tall shrub species with an average annual growth of up to 0.8-1.45 m or more are the most promising for creating energy plantations: *S. viminalis* L., *S. acutifolia*, *S. triandra*, *S. purpurea*, as well as *S. alba*, *S. pentandra* and *S. fragilis*, which have a tree life form (Figure 1). Among the native poplar species, *P. nigra* L., *P. alba* L., *P. tremula* L. with an average annual growth of 1.1-1.55 m in height are promising in the temperate climate zone of Ukraine for the creation of energy plantations.

In addition to the autochthonous species, Polish and Swedish energy varieties of the *Salix* genus have been intensively imported and tested in Ukraine over the past ten years, and native *Salix* and *Populus* varieties have been created and tested. The most popular source material for breeding is *S. triandra* and *S. viminalis*. According to M. Roik et al. (Roik et al., 2015), shrub species of the *Salix* genus produce 14 times more biomass than conventional forest, which allows obtaining 24-30 t/ha of dry biomass. The selection of *Salix* species is focused on increasing the yield of clones, increasing the potential for genetic improvement, increasing genetic diversity (variability) and shortening the production cycle (cultivation).

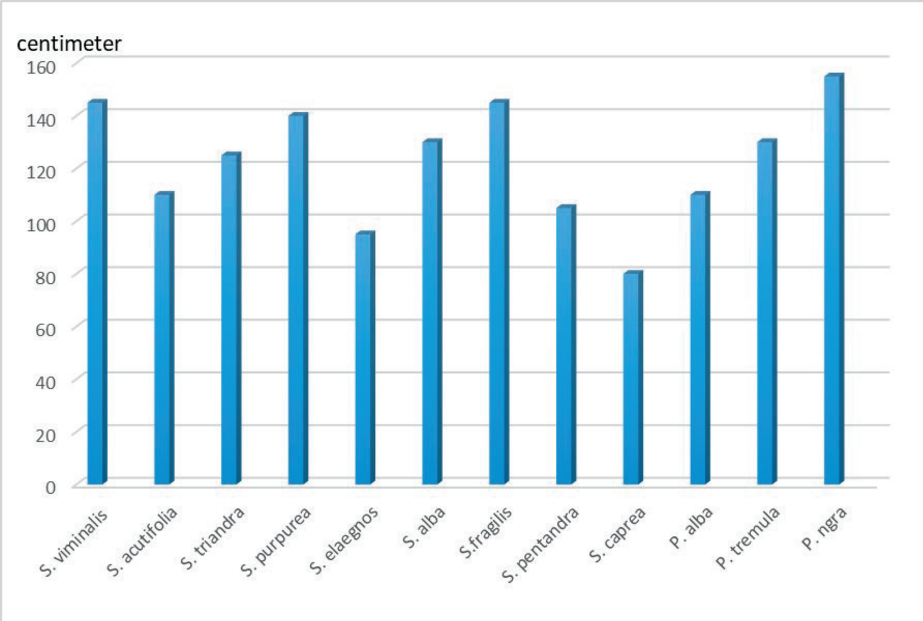

Figure 1. Average annual growth of three-year-old seedlings of *Salix* and *Populus* species in the forest-steppe of Ukraine

Since 2013, Ukraine has also started registering energy crop varieties of the *Salix* genus. As of February 2, 2023, 9 varieties of *S. viminalis* ('Panfyl's'ka 2', 'Marstyiana', 'Zbruch', 'Wilhelm', 'Linnea', 'Yevangelina', 'K2', 'M2', 'M3'), two varieties of *S. triandra* ('Yroslava', 'Panfyl's'ka'), two varieties of *S. fragilis* ('A3', 'Kozak', 'Adam 2') and one variety of *S. alba* ('N 1') (State register, 2023). The patent holders of these varieties are domestic scientific and educational institutions (Panfilska Research Station of the National Research Center "Institute of Agriculture of NAAS", Institute of Bioenergy Crops and Sugar Beet of NAAS, NUBiP of Ukraine), domestic and foreign companies (Salix Energy LLC (Ukraine), Jurelien Willov Briiding AB (Sweden), Lantmannen SW Seed AB. SE (Sweden) and private individuals.

A number of energy crop varieties of the *Populus* and *Salix* genera are being tested at the energy crops research and testing ground of the Leonid Pogorelyi Ukrainian Research Institute for Forecasting and Testing of Equipment and Technologies for Agricultural Production in Doslidnytske village, Obukhiv district. The experimental plots include *S. viminalis* and *S. triandra*, Swedish 'Inger', 'Tordis', 'Tora' and Polish '1047', '082', '1057' energy vatieties of *Salix* (Figure 2).

The creation of energy plantations from varieties of the genus *Populus* is being developed in detail in the conditions of Kyiv Polissia and Kharkiv region (Ukrainian Order "Sign of Honor" Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky). In total, the collection of URIFFM includes 34 clones of *Populus* varieties and six clones of *Salix* varieties of N. Starova's breeding 'Lisova Pisnia', 'Lukash', 'Mavka', 'Olimpijs'kyj vohon', 'Pechal'na', 'Pryberezhna' (Figure 3).

We also studied the growth of three-year-old seedlings of the *Salix* and *Populus* varieties at the biostationary facility of the Bila Tserkva NAU. The most promising in the conditions of the northern forest-steppe were *S. hybrida* 'Inger', *S. hybrida* 'Tardis', *S.* cv. 'Ternopilska', 'Tardif de Champange', *P.* cv. 'Weresina', *P.* cv. 'Witschtejna' (Figure 4). In the spring of 2018, we also laid a 0.5-hectare experimental plantation of energy willow of the 'Linnea' variety in Bila Tserkva NAU.

Figure 2. Test plantation of energy crops *S. viminalis* 'Tora' in Doslidnytske village, Obukhiv district

Figure 3. Variety test plantation in the Southern Forestry of the State Enterprise "Kharkiv Forest Research Station"

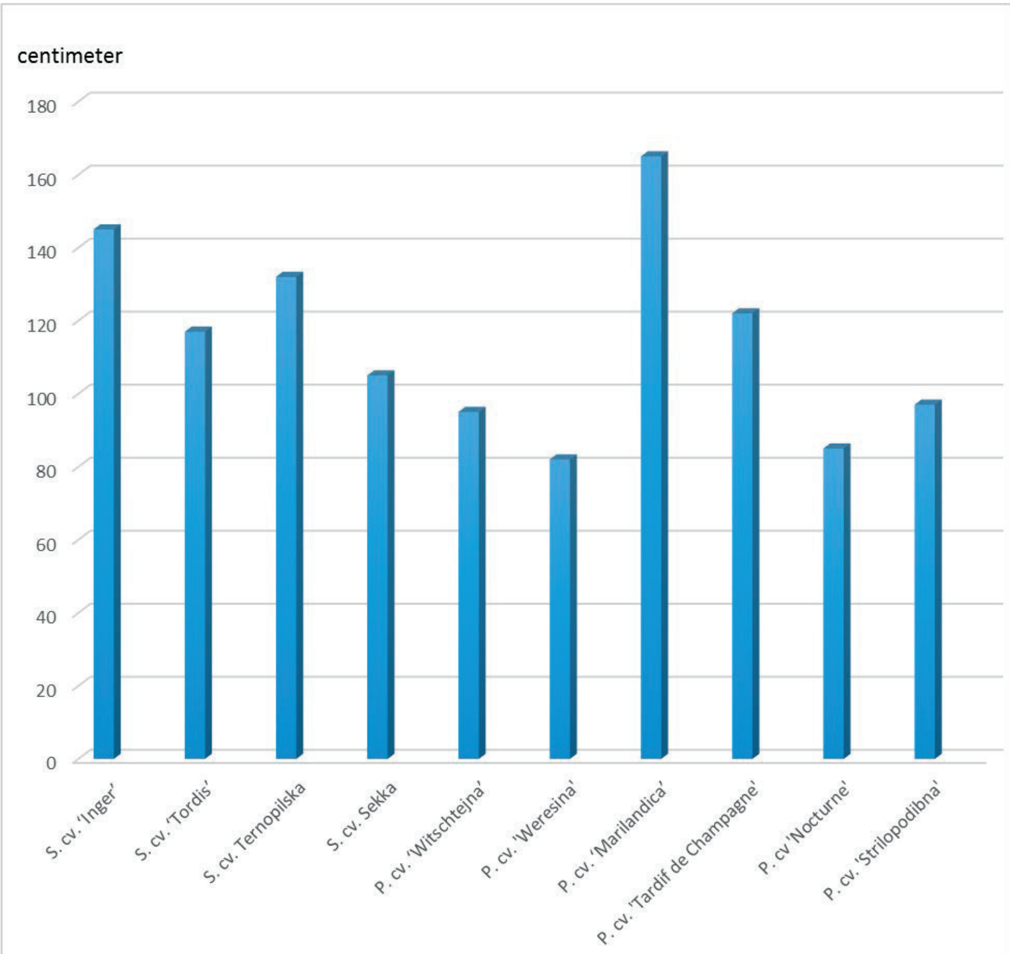

Figure 4. Average annual growth of three-year-old seedlings of *Salix* and *Populus* in the forest-steppe of Ukraine

In fact, the range of energy varieties of the *Salix* genus in Ukraine is much larger, but the long multi-year registration procedure significantly slows down the emergence of new varieties in the Ukrainian phytoenergy market. Another problem that hinders the development of bioenergy is the legal ban on planting *Salix* energy varieties on agricultural land, as *Salix* is classified as a forest crop in Ukraine. In neighbouring Poland, however, *Salix* is classified as an agricultural crop (Roik et al., 2015; Bohatov, 2021).

The development of *Salix* bioenergy is slowed down by the underdeveloped market for planting material for this crop. The market usually offers seedlings of different categories - licensed, unlicensed, Polish and Swedish varieties, and even seedlings cut right in the swamp. In Ukraine, only three companies work with licensed material, and two of them produce it only for their own needs.

Species and cultivars of the genus *Salix* and *Populus* in terms of calorimetric indicators produce from 7 to 20 tons of dry weight per hectare. For example, the yield of freshly cut shoots of *S. viminalis* is 40.7 - 47.3 m^3/ha, which is equivalent to 415 GJ × ha^{-1} of energy (Fuchylo et al., 2011). The estimated cost of production of one ton of fuel from *Salix* energy varieties is 1800-2000 euros (Ishchuk, 2014; Holland Plant Ukraine, 2022).

The definition of evaluation criteria to measure biomass quality is gaining increasing importance, especially in fast-growing forests.

Plant cell walls represent a vast reservoir of reduced carbon in the form of biopolymers, mostly cellulose, hemicellulose and lignin bound together in a complex network. Cellulose is the most abundant biopolymer on Earth and provides structural rigidity to plant cell walls. It is also a significant source of carbohydrates available for enzymatic hydrolysis and fermentation into liquid fuels, and represents the majority of substrates intended for second-generation biofuel production (Somerville et al., 2010). Hemicellulose is a heterogeneous biopolymer that adds strength to cells walls by linking cellulose microfibrils. Its composition differs greatly by plant species, but is mainly comprised of five-carbon sugar monomers and can therefore be a source of fermentable substrate using specialized or engineered microorganisms following chemical hydrolysis. Lignin has many important physiological roles in plants, including providing a hydrophobic surface in vascular tissues for water transport, and structural stability and resistance to disease and pest attack. However, it also presents a significant impediment to enzymatic cell wall depolymerization in liquid fuel production. Lignin has a higher energy density compared with cellulose and therefore is viewed as a desirable component for feedstocks used for thermal conversion. Lignocellulosic ethanol is an attractive biofuel because it is renewable, has reduced environmental impacts, and avoids competition with the food industry. The results regarding the quality of the investigated lignocellulosic substrates and its theoretical ethanol potential are illustrated in Table 1. We could mention that the concentrations of cellulose in *Populus alba* substrate are much higher in comparison with *Salix viminalis* substrate and pruning residues. The *Salix viminalis* substrate is richer in hemicellulose. The level of acid detergent lignin in *Populus alba* and *Salix viminalis* substrates were low as compared with the control, which had effect on the effective digestibility and decomposition of lignocellulose biomass. The estimated theoretical ethanol yield from cell wall carbohydrates averaged 510.4 L/t in *Salix viminalis* substrate and 505.4 L/t in *Populus alba* substrate, as compared with 476.3 L/t in pruning residues substrate. Several literature sources describe the composition of cell walls in willow and poplar energy biomass. According to Prosiński (1984) the lignocelulossic composition of *Salix alba* was 43.6% Seifert cellulose, 21.5% pentosans, 25.0% Klason lignin, but of *Populus alba* - 52.4% Seifert cellulose, 21.8% pentosans, 20.4% Klason lignin. Leple et al. (2007) remarked that *Populus trichocarpa* biomass contained 48.22-57.07% cellulose, 23.19-30.72% hemicellulose, 16.64-20.65% lignin. Karp&Shield (2008) reported that willow dry mass contained 55.9% cellulose, 14% hemicellulose, 19% lignin; poplar respectively 40% cellulose, 14% hemicellulose, 20% lignin bau in corn stover 35% cellulose, 28% hemicellulose, 10.4% lignin. Wróblewska et al. (2009) determined that young shoots of *Salix* *viminalis* content 39.29% Seifert cellulose, 17.05% pentosans, 26.04% Klason lignin. Mitsui et al. (2010) releved that dry matter of *Salix* spp. clones contained 78.9-81.2% hollocellulose, 27.2-32.3% lignin and 2.1-4.0% extractives with ethanol-benzen. Kim et al. (2014) reported that *Salix viminalis* var. *gigantea* stem was composed from 44.9% cellulose, 35.1% hemicellulose, 19.4% lignin and 0.6% of other extractives, the ethanol production 79.4 kg/t. Bajcar et al. (2018) remarked that the contents of cellulose, hemicellulose, and lignin in willow biomass was 44.6%, 32.1% and 14.5%, in rapeseed straw 41.4%, 29.8% and 18.6%; in wheat straw 38.1%, 30.6% and 21.3%, respectively. Majlingova et al. (2019) mentioned that willow mass contained 38.69% cellulose, 32.53% hemicellulose, 21.65% lignin and 11.25% extractives, but poplar- 36.60% cellulose, 32.55% hemicellulose, 24.69% lignin and 6.67% extractives.

Table 1. The cell walls composition and theoretical ethanol potential of studied biomass substrates

Indices	*Populus alba*	*Salix viminalis*	Apple tree pruning residues
Acid detergent fibre, g/kg	579	540	547
Neutral detergent fibre, g/kg	770	787	766
Acid detergent lignin, g/kg	73	91	110
Cellulose, g/kg	506	449	437
Hemicellulose, g/kg	191	247	219
Hexoses sugars, g/kg	89.8	80.60	78.17
Pentoses sugars, g/kg	31.40	41.80	36.02
Theoretical ethanol potential, L/tone	505.4	510.4	476.3

The chemical composition of dry biomass is a key factor that affects the caloric value and technologies for production of solid biofuels. The elemental composition of biomass is a significant asset that defines the amount of energy and evaluates the clean and efficient use of biomass materials, provides significant parameters used in the design of almost all energy conversion systems and projects, for the assessment of the complete process of any thermochemical conversion techniques (Lawal et al., 2021). The energy released during the combustion process is positively correlated with the carbon and hydrogen contents as a function of the energy value of these elements. In contrast, high oxygen and nitrogen values decrease the calorific value, decreasing the energy potential of the sold biofuel. Nitrogen, sulphur and chlorine contents are some of the main causes of air pollution from biomass combustion. A higher percentage of these elements generally results in a higher level of air contaminants being released. Ash content is one of the main factors of biomass quality, since higher amounts of ash diminishes the quality of solid fuels. The calorific value of a fuel can be expressed in two forms: the gross calorific value (GCV), or higher heating value (HHV) and the nett calorific value (NCV), or lower heating value (LHV). The HHV is the total energy content released when the fuel is burnt in air, including the latent heat contained in the water vapour and therefore represents the maximum amount of energy potentially recoverable from a given biomass source. In practical terms, the latent heat contained in the water vapour cannot be used effectively and therefore, the LHV is the appropriate value to use for the energy available for subsequent use. (MCKENDRY, 2002).

The elemental composition, ash content and calorific value of studied biomass is listed in Table 2. We found that the dry matter of the studied biomass contained 46.04-50.22% carbon, 5.84-6.00% hydrogen, 0.80-1.29% nitrogen, 0.04-0.18% sulphur, 0.04-0.07% chlor, 2.82-3.59% ash, 18.90-18.77 MJ/kg GCV and 17.69-18.46 MJ/kg NCV. The higher content of carbon and hydrogen, and the lower content of nitrogen, sulphur, chlorine and ash in *Populus alba* and *Salix viminalis* biomass which have positive impact on calorific value as compared with apple tree pruning residues. *Salix viminalis* biomass is characterized by higher level of carbon and optimal sulphur content, as compared with *Populus alba* biomass.

Table 2. The elemental composition, ash content and calorific value of studied biomass

Indices	*Populus alba*	*Salix viminalis*	Apple tree pruning residues
Carbon	47.83	50.22	46.04
Hydrogen	5.98	6.00	5.84
Nitrogen	0.80	0.89	1.29
Sulphur	0.16	0.07	0.18
Chlor	0.04	0.05	0.07
Ash content of biomass, %	2.82	3.53	5.59
Gross calorific value, MJ/kg	19.22	19.77	18.90
Nett calorific value, MJ/kg	17.91	18.46	17.69

Some authors mentioned various findings about the elemental composition and calorific value of biomass from *Salix* and *Populus* species. Xiong et al. (2008) reported that characteristics of willow biomass was 3.37% ash, 49.35% carbon, 6.31% hydrogen, 0.46% nitrogen and 19.09 MJ/kg HHV. Mitsui et al. (2010) found that calorific values of dried stem segments select willow (*Salix* spp.) clones were ranging from 18.7 to 19.1 kJ /g. Bilanzdija et al. (2012), raported that apple tree pruned biomass contained 73.50% volatile matters, 1.52% ash, 47.36% carbon, 6.42% hydrogen, 0.74% nitrogen, 45.30% oxygen, 0.18% sulphur and 17.06 MJ/kg LHV. Szyszlak-Barglowicz et al. (2012) remarked that willow coppice had 18 915 kJ/ kg heat of combustion and 17 688 kJ /kg heat value. Kang et al. (2014) noted that dry mass from poplar 79.7% volatile matters, 2% ash, 51.6 % carbon, 6.1% hydrogen, 0.6% nitrogen, 41.7% oxygen, 0.02% sulphur, but willow mass 74.2% volatile matters, 1.4% ash, 49.8 % carbon, 6.1% hydrogen, 0.6% nitrogen, 43.4% oxygen, 0.06% sulphur. Stolarski et al. (2014) found that *Salix viminalis* biomass contained 48.23-50.99% carbon, 5.67-5.88% hydrogen and 0.032-0.037% sulphur, 1.49-1.60% ash, 19.40-19.59 MJ/kg HHV, but *Salix dasyclados* 47.04-49.91% carbon, 5.49-5.94% hydrogen and 0.038-0.046% sulphur, 1.59-1.71% ash, 19.40-19.53 MJ/kg HHV. Williams et al. (2016) mentioned that the shrub willow contained 84.0% volatile matters, 1.5% ash, 50.3% carbon, 13.6 % fixed carbon, 6. 0% hydrogen, 0.36% nitrogen, 42.6% oxygen, 0.04% sulphur; hybrid poplar 84.0% volatile matters, 1.3% ash, 50.0% carbon, 14.6% fixed carbon, 6.0% hydrogen, 0.35% nitrogen, 42.8% oxygen, 0.03% sulphur, but herbaceous biomass respectively 79.1% volatile matters, 5.5% ash, 47.4% carbon, 15.4% fixed carbon, 5.8% hydrogen, 0.75% nitrogen, 41.0% oxygen, 0.10% sulphur. Monedero et al. (2017) reported that willow stem contained 83.59% volatile matters, 1.88% ash, 48.84% carbon, 6.18% hydrogen, 0.46% nitrogen, 0.03% sulphur, 0.0% clor, 17.98 MJ/kg LHV dry basis; poplar stem contained 82.37% volatile matters, 3.00% ash, 51.84% carbon, 6.39% hydrogen, 0.16% nitrogen, 0.04% sulphur, 0.01 % clor, 17.93 MJ/kg LHV dry basis. Bajcar et al. (2018) noted that raw willow mass is characterized by 10.3% moisture, 25.5% volatile matters, 3.15% ash, 48.1% carbon, 5.55% hydrogen, 0.55% nitrogen, 53.1% oxygen, 17.5 MJ/kg LHV, but torrefied mass 7.96-9.12% moisture, 23.1-44.9% volatile matters, 3.17-3.72% ash, 48.2-55.5% carbon, 3.64-5.87% hydrogen, 1.15-1.48% nitrogen, 42.2-44.9% oxygen, 19.2-21.5MJ/kg LHV. Dyjakon (2018) releved that pruning biomass had 0.8% ash, 19.31 MJ/kg HHV and 18.05 MJ/kg LHV. Gudima (2018) mentioned that studied *Salix* varieties contained 1.54-1.75% ash, 19.12-19.75MJ/kg GCV and 17.88-18.51 MJ/kg NCV. Pavlenco (2018) found that collected pruned biomass had 24.31-40.49% moisture and dry mass was characterized by 44.31-47.13% C, 5.37-6.11% H, 0.28-0.32% N, 0.02-0.04% S, 0.76-1.67% ash, 20.11-21.40 MJ/kg GCV and 18.78-20.07 MJ/kg NCV. Majlingova et al. (2019) revealed mentioned that willow mass had 1.28% ash, 19.63 MJ/kg HHV and 16.33 MJ/kg LHV, but poplar mass - 2.59% ash, 19.4 MJ/kg HHV and 16.18 MJ/kg LHV. Ţîţei & Roşca (2021) mentioned that calorific value of biomass from *Salix* and *Populus* species varied from 19.00 MJ/kg HHV to 19.5 MJ/kg HHV. According to Stachowicz & Stolarski (2023), the harvested willow mass contained 49.75% moisture, 78.38% volatile matters, 1.25% ash, 53.25% carbon, 20.37% fixed carbon, 5.97% hydrogen, 0.38% nitrogen, 0.016% sulphur, 0.019 % clor, 19.63 MJ/kg

50% carbon, 6.2% hydrogen, 0.6% nitrogen, 43.10% oxygen, 0.9% sulphur, 19.63 MJ/kg high heating values; poplar mass - 56.52 % moisture, 77.83% volatile matters, 1.67% ash, 53.46% carbon, 20.50% fixed carbon, 5.90% hydrogen, 0.43% nitrogen, 0.025% sulphur, 0.027% clor, 19.84 MJ/kg; black locust mass 38.89% moisture, 77.86% volatile matters, 1.40% ash, 52.60% carbon, 20.74% fixed carbon, 5.94% hydrogen, 0.91% nitrogen, 0.033% sulphur, 0.032 % clor, 19.46MJ/kg high heating values.

CONCLUSIONS

Therefore, promising plants are species and varieties of the genera *Salix* L. and *Populus* L., which are characterized by rapid biomass growth rates. Studies have shown that the annual growth of species and varieties of the genus *Salix* L. is 80-145 cm and of the genus *Populus* L. - 120-165 cm.

The *Salix viminalis* and *Populus alba* phytomass contained 2.82-3.53% ash, 44.9-50.6 % cellulose, 19.1-24.7% hemicellulose, 7.3-9.1% acid detergent lignin, 47.83-50.22% C, 5.98-6.00% H, 0.80-0.89% N, 0.07-0.16% S, 0.03-0.05 % Cl, 19.22-19.77 MJ/kg HHV and 17.91 18.46 MJ/kg LHV, but in apple tree pruning residues 5.59% ash, 43.7% cellulose, 21.9% hemicellulose, 11.0% acid detergent lignin, 46.04 % C, 5.84% H, 1.29% N, 0.18% S, 0.07% Cl, 18.90 MJ/kg HHV and 17.69 MJ/kg LHV. The estimated theoretical ethanol yield from cell wall carbohydrates averaged 510.4 L/t in *Salix viminalis* substrate and 505.4 L/t in *Populus alba* substrate, as compared with 476.3 L/t in pruning residues substrate.

The rapid development of global bioenergy causes the need to search for and develop fundamentally new approaches to plantation forestry. The introduction of plantation forestry in Ukraine will help reduce resource pressure on other categories of forests, increase the country's forest coverage and productivity of plantations, and reduce the time required to grow wood for further use for energy purposes. At the same time, a number of economic, environmental and social problems in rural areas may be resolved. Utilizing Ukraine's resource potential to the fullest extent, i.e. reforestation of vacant agricultural land, makes it possible to obtain an environmentally friendly renewable energy source in the form of biomass. The development of the latest biomass conversion technologies and their application in the energy sector of Ukraine and Moldova opens up the possibility of establishing energy independence for both countries. Accordingly, the economic situation in the countries will improve and the welfare of the population will increase.

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