

Survival Rate of Willow Depending on the Storage Methods of Planting Material

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ABSTRACT

The paper presents the research results of the survival rate of willow planting material depending on the storage methods and varietal peculiarities. The studies of the storage methods of planting material and their effect on the survival rate of cuttings and shoots were carried out in the years of 2019–2021 in the experimental field of the Institute of bio-energy crops and sugar beets, Ukraine. Two willow (*Salix* spp.) species: three-stamina variety Panfilivska and common willow variety Zbruch, were studied. Rot-affected cuttings and shoots as well as the number of the sprouted ones were monitored during the period of their placing in the storage till their planting in the field. It was found that both cuttings and shoots stored well in all treatments. During the storage, a small number of sprouted cuttings and disease - affected ones were recorded. Rot-affected cuttings and shoots of both varieties were recorded only when they were stored in plastic bags both with and without lime treatment of incisions. Rot-affected planting material was not recorded when other storage methods were used. It was established that during the storage moisture losses in cuttings and shoots of both varieties were not seen on any record date and as far as the content of nutrition elements (NPK) is concerned, there was a decreasing tendency. It was found that the survival rate of planting material depended on both variety peculiarities and its species, and it was high even on the first record date. Common willow variety Zbruch had the highest percentage of survival rate of cuttings and shoots as compared with the three-stamina variety Panfilivska. All storage methods of cuttings and shoots at air temperature 3–5°C ensure their good shelf-life with small damages caused by disease and slight germination in some years. The survival rate of planting material depended on both varietal peculiarities and its species. The highest percentage of survival rate of cuttings and shoots was typical for common willow variety Zbruch as compared with three-stamina variety Panfilivska.

Keywords: willow species, variety, shoots, cuttings, container, plastic bag.

INTRODUCTION

Bioenergetics plays a special role in increasing the energy independence of Ukraine, as it could satisfy most of energy needs of farm enterprises (Doronin et al., 2018). Besides, the development of bioenergetics could help solve numerous ecological, energy and social problems (Horba et al., 2017). The development and

introduction of the technologies aimed at receiving the energy from bio-mass are an efficient way to reduce the consumption of fossil kinds of fuel which will guarantee a true energy and economic independence of Ukraine.

The most promising bio-energy crops for Ukraine are sugar beets, sugar sorghum, switchgrass, miscanthus (Mozharivska, 2013), willow and poplar (Fuchylo et al., 2009). The introduction

of these crops will ensure the feasibility to receive from 0.72 to 4.1 t ha⁻¹ of oil products per hectare; the efficiency the analysis of the consumption efficiency of energy resources in industrialized countries and the dependence on their import (2015). Among woody plants willow (*Salix* spp.) is used as the main energy crop in the world as it enables to create highly productive plantations with a long term of existence (Wang et al., 2015). In Ukraine several willow varieties of different species of both local and foreign selection are recommended for cultivation (Barna, 2002).

In the USA the areas under poplar are larger than those under willow because the yield capacity of poplar dry matter is 1.1–2.1 times higher than that of willow (Volk, 2018); however it is expedient to increase these areas in view of their high ecological potential (Tumminello, 2015). They facilitate a stable development of the agro-industrial complex, as they have several ecological advantages as compared with annual agricultural crops (Bressler, 2017).

The prospects of the use of hybrids were confirmed by the research carried out in the state of Minnesota; there in the first three-year cultivation cycle the productivity of the plantations of hybrid willow varieties was 7.42–16.0 t/ha, whereas in the plantations of native willow it was only 0.69–1.83 t/ha of dry mass per year (Zamora, 2014).

However, there is a lack of information concerning the harvest, the storage of planting material and the effect of its quality on the formation of willow productivity. The research of these technology elements will assist in the creation of favourable conditions for a maximal survival rate of willow cuttings and shoots as well as in the increase of a propagation coefficient of planting material. The use of absorbent, when cuttings are planted, would provide an available and proper amount of moisture in a dry period, decrease a contrast fluctuation of moisture supply of the plants in a vegetative period, and in turn would have a serious impact on the output of seedlings.

A wide introduction of energy willow into production is not possible without the availability of a proper amount of planting material, which is why it is urgent to develop the technology elements which provide good quality cuttings and shoots.

A rapid development of world bioenergetics enhances the production and processing of renewable energy raw materials. Wood is one of the oldest and the most promising energy sources in future. In industrialized countries it is forbidden

to burn wood except for shrubs. Hence the cultivation of fast-growing species of trees and shrubs on special energy plantations, unsuitable for growing agricultural crops, became the solution of the problem. These plantations make it possible to receive a lot of bio-mass on a relatively small area and for a short period of time which exceeds the potential of traditional forests (Campbell et al., 2012; Caslin et al., 2013).

All species which, under favorable conditions, can produce an annual increase of dry mass without leaves, belong to fast-growing woody species (ones). The treatment of plants with physiological solutions caused their more intensive growth (Major, 2017).

In temperate latitudes various species of willow and poplar as well as their hybrids meet these criteria. The cultivation and maintenance of such plantations consist in planting the cuttings of fast-growing willow varieties usually in paired rows. In the period of termination and restoration of a sap-movement an above-ground part of shrubs is cut in every 4 years with help of a special technique, grinding into chips or stacking to be dried (Tharakan et al., 2005). In spring after each cutting an abundant young growth appears and after 2–4 years it is cut again to receive energy raw materials. According to this scheme the plantations are intensively used for 20–25 years (Dimitriou et al., 2011).

On well-organized plantations, it is possible to obtain over 130 t of fresh biomass per hectare per year provided irrigation is applied and a two-year harvesting cycle is used. Without irrigation one can expect the yield capacity equal to 30–35 t (Stajic, 2016).

The technology of the creation of energy willow plantations, in particular in the first year, is similar to the cultivation of row agricultural crops. In the countries of the European Union willow plantations on agricultural areas are classified as perennial plantations and stimulated by state subsidies.

RESEARCH CONDITIONS AND METHODS

The research program envisaged the studies of the efficiency of different storage methods of planting material – cuttings and shoots and some principles of the formation of the above-ground phyto-mass of bio-energy willow depending on varietal peculiarities. Field and laboratory trials

were carried out at the Institute of bio-energy crops and sugar beets of NAAS, Ukraine and in the experimental field (Ksaverivka village 2, Kyiv region) in 2019–2021. The scheme of the trial implied the storage of cuttings and shoots at air temperature 3–5°C in the container, in a sand layer and in plastic bags with and without lime treatment of the scissions. Scissions were treated with lime to prevent diseases of cuttings and shoots. Annually, planting material was placed in the storage on November 25th. During the storage in dynamics – every 24–25th date of a month up to cutting and shoot planting, the number of germinated and disease affected ones was defined as well as the content of nutrition elements and their moisture. The date, when planting material was placed in the storage, was the control for the mentioned indicators.

The research was carried out with two willow (*Salix* spp.) species: three-stamina (*Salix triandra* L.) variety Panfilivska and common willow (*Salix viminalis* L.) variety Zbruch. The total plot area was 990.88 m², a record plot area was 5.63 m², fourfold replication. The placement of treatments and replications was randomized. Willow was planted in a planting distance 70 cm in a row, an inter-row was 70 cm.

In order to plant a large plantation of willow, which is better to do in spring, it is advisable to have a sufficient amount of planting material that can be often a problem in spring when field work is in process and labour resources are in deficit. With this in mind, studies were performed for harvesting and storing planting material in autumn and in spring to be planted in spring. Cuttings were 20–25 cm long with a diameter 2.0–0.7 cm and had 4 well-developed buds. Upper and lower scissions were made at 0.5–1.0 cm from a bud. Shoots were at least 1.0 m long.

The experimental field of the Institute of bio-energy crops and sugar beets of NAAS is situated in the central part of the Right-bank Forest steppe of Ukraine; this is the zone of unstable moistening which is characterized by a temperate continental climate. The topography of the experimental field is a slightly wavy plain with a small slope of the surface. The soil of the experimental field is typical leached chernozem, medium-deep, low-humus, rough-dusty-light loam, on carbonated loess. Humus content is 2.64% (by Turin method), the content of labile phosphorus and exchangeable potash (by Chyrykov) is 180 and 160 mg kg⁻¹, respectively, whereas the nitrogen content, which

is easily hydrolysed (by Cornfield), is 280 mg kg⁻¹. Soil acidity (pH) is 6.6. The depth of humus horizon is 100–120 cm (Volkodav, 2000).

Weather conditions of a vegetative period were favourable for the growth and development of agricultural crops. In the years under study a vegetative period by a temperature regime was closer to the average long-term indicator. An average daily temperature exceeded an average long-term indicator by 2.0–2.2°C, except for May which was colder. As to moisture supply of the plants during a vegetative period there was moisture deficit (38–47.7 mm), precipitations were distributed unevenly by months. During the period of planting and germination (March) an average daily air temperature was closer to an average long-term indicator, and it was equal to 5.2–5.7°C; it was higher only by 0.3°C which proved that the plants had enough warmth. Moisture deficit was insignificant – 6.7–9.8 mm, which had its effect on survival rate of cuttings.

RESEARCH RESULTS AND DISCUSSION

From a biological point of view, storage means the prolongation of life with minimal losses, the preservation of high quality which can be achieved through slowing down the processes of life activity (respiration) in this period. The main task of planting material storage in a winter period is to maintain optimal indicators of temperature and humidity which play the most important role in the process which take place in cuttings and shoots. Important physiological processes for further crop cultivation, namely the formation of reproductive organs, take place during the storage of planting material. The crop productivity depends on the conditions in which these processes take place. Hence, it is important to choose optimal regimes and methods of the storage of planting material; those which will ensure minimal mass losses of planting material from physiological and microbiological processes, i.e., respiration and evaporation of moisture (Fuchylo, Hnap, 2018).

Rot affected cuttings and shoots and the number of germinated ones were monitored in dynamics – from placing them in the storage to planting them in the field. Both cuttings and shoots stored well in all treatments. During the storage, a great number of germinated cuttings of three-stamina willow, variety Panfilivska, and common willow,

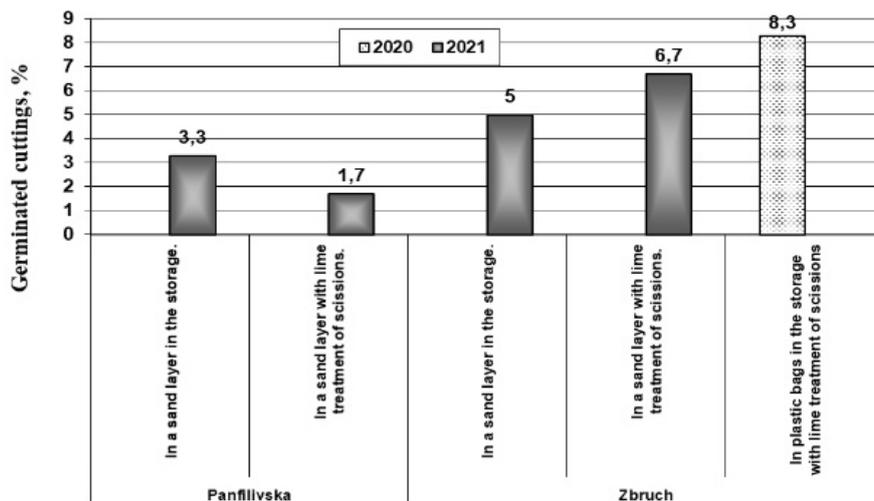


Figure 1. Amount of willow planting material which germinated depending on storage methods (in 2020–2021)

variety Zbruch, were recorded in 2020 and 2021 depending on storage methods (Figure 1).

In 2020, only 8.3% of common willow cuttings, variety Zbruch, germinated when they were stored in plastic bags and scissions were treated with lime. Cutting germination of both varieties was not recorded when other storage methods were used. In 2021, slight cutting germination of both varieties was seen when they were stored in a sand layer both with and without lime treatment of scissions, the number of germinated cuttings of variety Zbruch being larger than that of variety Panfilivska. In 2019, there were no germinated cuttings of either variety under all storage methods. When the planting material was kept in a stationary storage under controlled conditions

of Yaltushkivska RES in all years under study neither germinated nor rot affected cuttings and shoots were seen.

When the planting material was kept in the storage of the experimental field of the Institute rot affected planting material of both varieties was recorded (Figure 2).

Rot-affected cuttings and shoots were seen only when they were stored in plastic bags both without and with scission lime treatment. There was no rot affected planting material under other storage methods. In 2019 cuttings of the Panfilivska variety were 100% disease affected when scissions were lime treated, and only 5% - without this treatment. Rot affected shoots of this variety were not recorded. For variety Zbruch, in 2019

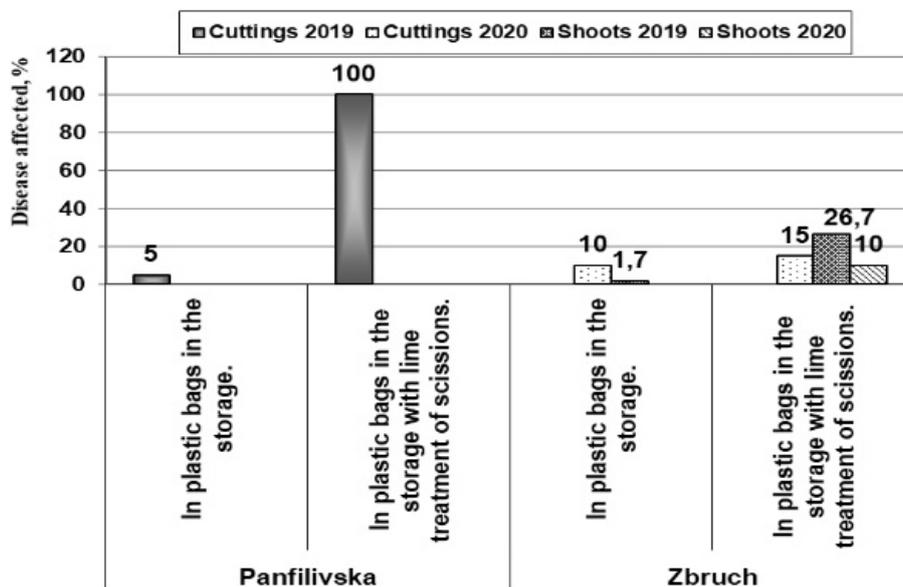


Figure 2. Disease damage of willow planting material depending on its storage methods (in 2019–2020)

Table 1. Quality of willow planting material depending on its storage methods (average of 2019–2021)

Treatment		Record date	Moisture %	Content of nutrition elements %		
Variety	Kind of planting material			Nitrogen	Phosphorus	Potash
Panfilivska three-stamina	Cuttings	Control – placing in the storage	32.21	1.30	1.68	2.10
		26.12.	30.49	1.26	1.64	2.16
		25.01.	34.43	1.19	2.33	1.50
		25.02.	33.82	1.13	1.43	1.26
		25.03.	35.95	1.03	1.43	1.24
	Shoots	Control – placing in the storage	31.48	1.30	1.68	2.07
		26.12.	32.83	1.19	1.54	2.26
		25.01.	38.83	1.14	1.54	1.60
		25.02.	35.55	1.12	1.42	1.24
		25.03.	38.91	1.04	1.41	1.22
Common willow Zbruch	Cuttings	Control – placing in the storage	28.08	1.10	1.61	1.88
		26.12.	27.76	1.10	1.54	1.79
		25.01.	35.85	1.19	1.50	1.44
		25.02.	34.22	1.05	1.36	1.26
		25.03.	35.68	1.04	1.37	1.20
	Shoots	Control – placing in the storage	26.93	1.09	1.58	1.85
		26.12.	29.51	1.08	1.48	1.77
		25.01.	33.05	1.17	1.44	1.39
		25.02.	34.22	1.07	1.33	1.21
		25.03.	36.81	1.03	1.35	1.18

rot-affected cuttings amounted to 10–15%, shoots – 26%, in 2020 – 10%. In 2021, planting material of both varieties stored well, no signs of disease damage were seen. On the basis of the amount of germinated planting material and its disease damage rate, the conclusion is: cuttings and shoots of three-stamina willow, variety Panfilivska, store better depending on a storage method.

One of the main processes which take place during the storage of planting material is evaporation of moisture. Beginning from the termination of nutrition and during the whole storage process, moisture of the planting material evaporates easily through its surface, which is why, due to an anatomical structure and a chemical composition, the water-retaining ability is very low. Water is not a passive component of juicy raw material; it is one of the main factors which define the intensity of biological processes and the quality of the output (Fausto, 1963). It was found out that on all record dates during the storage no moisture loss in cuttings and shoots of both varieties was recorded.

In contrast, it was somewhat higher as compared with the control (Table 1).

As far as the content of nutrition elements (NPK) is concerned there was a decreasing tendency both in cuttings and shoots of both varieties, their lowest content was on the last record date – before planting; this fact proves that during the storage life processes took place and nutrition elements were used for life activity of cuttings and shoots.

Small loss of nutrition elements during the storage of cuttings and shoots did not have a serious effect on their survival rate under field conditions after planting (Figure 3).

Survival rate of planting material depended on both varietal peculiarities and on its species, and it was high even on the first record date. A higher survival rate percentage of cuttings and shoots was typical for common willow, variety Zbruch; there was no reliable difference in relation to the kind of planting material. Three-stamina willow, variety Panfilivska, had a reliably lower survival rate of cuttings and shoots, in particular on the first days of germination.

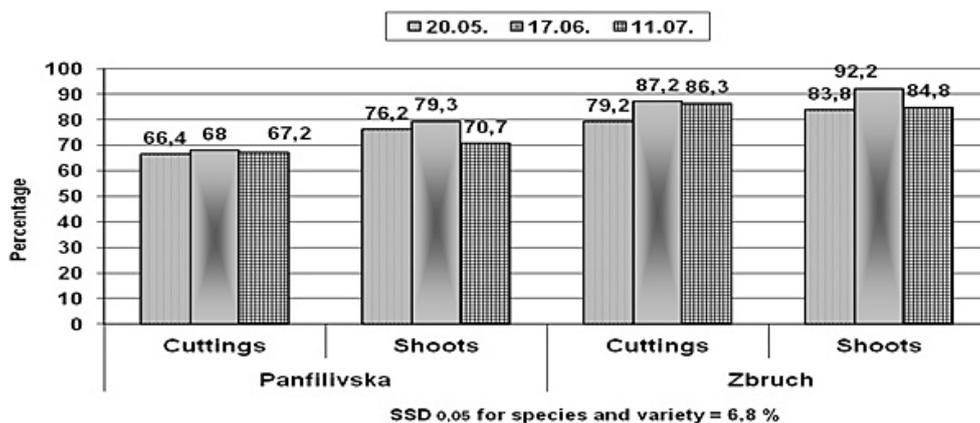


Figure 3. Survival rate of willow planting material depending on its species and varietal peculiarities (average of 2019–2021)

Survival rate of planting material depended on its storage methods (Table 2).

On the first record date, the highest survival rate percentage of cuttings (81%), variety Panfilivska, was received when they were stored in plastic bags with lime treatment of scissions, and that of shoots – in a sand layer with and without lime treatment of scissions and in plastic bags with and without lime treatment of scissions. When other storage methods were used, survival rate of cuttings and shoots was significantly low, even lower than on the last record date, when its percentage did not change, than on the first date which was due to their drying.

The survival rate of planting material of common willow, variety Zbruch, was better for both cuttings and shoots (Table 3).

The highest survival rate of the common willow cuttings variety Zbruch on the first record date was received when they were stored in a sand layer with and without lime treatment of scissions and in plastic bags without lime treatment of scissions.

A high survival rate of the shoots of this variety was monitored using all storage methods except for one – storage in plastic bags with lime treatment of scissions, where a survival rate percentage was reliably lower as compared with other storage methods. On the last record date, the survival rate of the cuttings and shoots of variety Zbruch was much higher as compared with that of variety Panfilivska.

Summing up the obtained results a conclusion can be made that it is expedient to keep the cuttings of variety Panfilivska in plastic bags with lime treatment of scissions and to store shoots using all

Table 2. Survival rate of three-stamina willow, variety Panfilivska, depending on its storage conditions (average of 2019–2021)

Kind of planting material	Treatment	Survival rate on record date %		
	Storage method	20.05.	17.06.	11.07.
Cuttings	In containers in the storage	48	51	60
	In containers with lime treatment of scissions	67	64	67
	In sand layer in the storage	73	85	71
	In sand layer with lime treatment of scissions	71	66	73
	In plastic bags without lime treatment of scissions	73	74	65
	In plastic bags with lime treatment of scissions	81	81	81
Shoots	In containers in the storage	58	79	73
	In containers with lime treatment of scissions	73	79	73
	In sand layer in the storage	81	83	77
	In sand layer with lime treatment of scissions	81	80	69
	In plastic bags without lime treatment of scissions	83	77	69
	In plastic bags with lime treatment of scissions	81	78	63
LSD _{0,05}		12.9	11.9	10.3

Table 3. Survival rate of common willow, variety Zbruch, depending on its storage conditions (average of 2019–2021)

Treatment		Survival rate on record date %		
Kind of planting material	Storage method	20.05.	17.06.	11.07.
Cuttings	In containers in the storage	77	78	71
	In containers with lime treatment of scissions	73	84	88
	In sand layer in the storage	85	92	96
	In sand layer with lime treatment of scissions	88	84	90
	In plastic bags without lime treatment of scissions	83	94	92
	In plastic bags with lime treatment of scissions	69	91	81
Shoots	In containers in the storage	83	91	85
	In containers with lime treatment of scissions	88	94	83
	In sand layer in the storage	81	93	85
	In sand layer with lime treatment of scissions	88	91	83
	In plastic bags without lime treatment of scissions	90	98	94
	In plastic bags with lime treatment of scissions	73	86	79
LSD _{0.05}		12.9	11.9	10.3

storage methods except for keeping them in containers. It is advisable to keep the cuttings of variety Zbruch under all storage methods except for keeping them in containers and plastic bags with lime treatment of scissions, and to keep shoots using all storage methods except for one – storing in plastic bags with lime treatment of scissions.

CONCLUSIONS

All storage methods of willow cuttings and shoots at air temperature 3–5°C ensure their high shelf life with slight disease damages and insignificant germination in some years. The survival rate of planting material depended on both varietal peculiarities and its species. Common willow, variety Zbruch, showed the highest survival rate percentage of cuttings and shoots as compared with three-stamina willow, variety Panfilivska.

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