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YIELD IMPROVEMENT OF WHITE MULBERRY IN POLAND BY MODERN CULTIVATION MEASURES

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ABSTRACT

Numerous applications of white mulberry significantly increase the value of this plant. Due to the bioactive substances contained in the leaves, food products with the addition of mulberry are very popular and farmers are increasingly interested in the production of leaves as herbal raw material. Additionally, mulberry leaves constitute feedstock for mulberry silkworm larvae and that is why planting mulberry is essential for the production of silkworm cocoons. This plant may also be used in the energy sector to provide large amounts of biomass. A greater demand for mulberry raw material results in an increase in the cropped area, while thanks to its low soil requirements mulberry may be cultivated throughout the country.

Presented Polish methods of white mulberry cultivation are the first agricultural development since the 1980s. The article presents the requirements of mulberry and cultivation measures that limit outlays in the production of biomass while providing a high yield of good quality material.

KEY WORDS: *white mulberry cultivation, fertilization, planting, cultivation measures*

INTRODUCTION

White mulberry (*Morus alba* L.) is a deciduous tree species originating from Asia. It grows up to 15 m in height and its characteristic traits is the presence of milky sap in shoots. It is a dioecious plant with small, inconspicuous flowers and sweet compound fruits, which may be white, pink, purple or black coloured. Leaf shape varies greatly, although leaf blades are typically cordate and serrated on the margins. The name of white mulberry originates from the whitish bark colour and not from fruit colour, as it is commonly erroneously believed. This tree is rather frequently found, particularly near schools, railway stations or as single plantings in cities.

Numerous applications for white mulberry considerably enhance the value of that plant. Thanks to the contents of bioactive substances foodstuffs supplemented with mulberry are considered attractive by consumers; thus farmers are increasingly often interested in the production of leaves as herbal material. Additionally, mulberry leaves constitute feed for silkworm larvae, thus the tree plantings are required as the basis for silkworm cocoon production. This plant may also be used in the energy sector yielding large amounts of biomass. An increase in the demand for mulberry material has a positive effect on the increase in cropped area, while low soil requirements facilitate mulberry cultivation throughout Poland.

CLIMATIC AND SOIL REQUIREMENTS OF MULBERRY

White mulberry is a thermophilic and heliophilous plant. The optimal temperature for its growth ranges from 20 to 30°C. In Poland mulberry develops buds relatively late, typically in the period from late April to the beginning of May. A decrease in temperature below 12°C inhibits growth, while May frosts cause frost damage of buds and flowers (Litwińczuk 1993). However, this plant has a short regeneration period and the flower and leaf structures recover after approx. 2 weeks. In the winter prolonged, snowless periods with frosts of -20 to -30°C cause partial or complete frost damage of 1-year old shoots. Nevertheless, this plant may be grown

throughout Poland. It grows best in regions with the vegetation season of approx. 200 days. In the north-east and mountainous regions mulberry should be protected against frost. This species grows best on well-isolated, slightly moist permeable soils rich in minerals. This plant will not grow on arid, stony, clayey, water-logged or marshy soils. The neutral and slightly alkaline soil reaction is optimal, while the groundwater table should not be higher than 1 - 1.5 m below the ground.

REPRODUCTION

Generative reproduction by seed sowing is the cheapest and the easiest way to obtain seedlings. Nevertheless, the obtained material may differ from mother plants in some features (Choynowski 1986). An old mulberry tree of Polish variety Żółwińska wielkolistna may produce 10-20 kg of fresh fruit, from which 200-400 g of seeds are obtained (Choynowski 1979). Moreover, based on 1 kg of seeds farmer may obtained about 20.000 -30.000 of seedlings (Choynowski 1986).

Seeds are sown in March or April; however, soil temperature needs to be min. 12°C. Mulberry seeds have to be covered with small-grained gravel with a layer of max. 0.5-1 cm. Seeds need to be watered until the soil is completely saturated, while successive waterings should maintain the soil constantly moist (Łochyńska 2016).

In a properly prepared seedling nursery massive seedling emergence is observed after 14-25 days after sowing. When seedlings have 2-3 leaves, they need to be thinned to provide better developed plants with 1-2 cm spacing. Seedling nurseries require frequent weeding and soil loosening to prevent crust formation on the soil surface.

Vegetative reproduction is carried out through layering, grafting, budding or woody cuttings [Łochyńska 2016]. In contrast to generative propagation, this process ensures obtaining individuals identical to the mother plant. This is important when planning herbal plantations, where leaf biomass plays the most important role. In this case, material from plants producing the largest leaf blades is obtained for propagation. However, vegetative propagation through grafting is not economically viable (Bhau 1999). Mulberry tree improvement through conventional breeding is slow and also difficult due to its heterozygous nature.

In recent years, scientists have also developed a method of micropropagation in *in vitro* cultures using different explants, such as stem, shoot tip and nodal segments (VijayaChitra and Padmaja 1999), axillary buds (Attia et al. 2014), hypocotyl and cotyledon (Bhatnagar et al., 2001) and leafs (VijayaChitra and Padmaja 2005). In vitro cultures has been attempted with various degrees of success among mulberry varieties (Rao et al. 2010). However, the obtained plants retain the morphology and physiology of the parent material. *In vitro* cultivation technology makes it possible to obtain seedlings in shorter period and at a lower cost. However, this method is based mainly on laboratory work, hence it is not easily available for the farmer.

PLANTINGS

Seedlings are planted in the nursery in the spring. Plants to be grown for shrubs are planted at a stocking of 80 000-120 000/ha, at a row spacing of 40-50 cm and plant spacing in a row of approx. 15-20 cm. Prior to planting the seedling roots have to be shortened to approx. 15-20 cm. Care needs to be taken for the root crown to remain 2 cm below the ground and to prevent roots from being folded (Choynowski 1986). The best time to plant mulberry seedlings is in the autumn, after leaf shedding and before frosts (October-December). The root system needs to be pruned to a length of approx. 20 cm and covered with soil so that the root crown is below the ground surface. For the winter season it is recommended to form a berm of approx. 15 cm over the root crown (Łochyńska 2016).

For permanent mulberry plantings healthy 2-year old seedlings need to be selected. Older seedlings are recommended for locations at a greater risk of animal feeding, boring and mechanical damage, in idle land and buffer strips.

When establishing a field plantation mulberry seedlings need to be planted at a spacing of approx. 1 m apart, with 3 m spacing between rows. Single row hedgerows require shrubs to be planted at a spacing of 30-40 cm, while for double row hedgerows it is 50 cm between the rows and the seedlings (Table 1).

Table 1. Spacing of white mulberry seedlings in specific planting types.

Planting type	Row spacing [m]	Spacing between seedlings [m]
Field plantation	3	0.7-1
Compact plantation	1.5-2	0.7-1
Single row hedgerow	-	0.3-0.4
Double row hedgerow	0.5	0.5
Plantation on idle land	2	0.7-1
Tree and shrub plantations	3-4	3-4

The area planted with mulberry cultivation should be plowed deeply with a plow to a depth of 30-35 cm, then the soil should be properly leveled (Datta 2000). Other crop plants may be grown in inter-row spaces in mulberry plantations. Plants developing well in the company of mulberry include potatoes, beans, buckwheat, pea, red beets as well as forage plants, which additionally supplement resources of available nitrogen in the soil, e.g. sweet lupine, mustard, clover, lucerne and bird's foot (Kopański 1955).

Mulberry trees may be used starting from 2-3 years after planting. Tall-stemmed, old trees and plantings after a prolonged period of use require intensive regeneration through short trimming of shoots to produce new, young shoots with large leaf blades (Sharma and Madan 1994).

A properly maintained, well-tended mulberry plantation provides 2 harvests of leaves within one vegetation season. It is recommended to collect the harvest from trees in June and August, maintaining an approx. 2-month period for plant regeneration. Intensively exploited plantings require organic or mineral fertilization to be repeated annually in order to ensure good seedling vigour (Chinnaswamy and Hariprasad 1995).

TENDING FOR YOUNG MULBERRY TREES

Plant trimming is the primary tending intervention. One-year old seedlings are pruned to a height of approx. 10-15 cm, forcing shoot tillering (fig. 1). For the purpose of leaf harvest low and sparsely branched shrubs should be formed to promote production of large leaf blades (figures 2-4). It is best to prune the seedlings in early spring after frost risk passes (March-April). In the successive years lateral shoots are cut at the main shoot, leaving 3-4 shoots longer at approx. 50 cm (fig. 2-4).

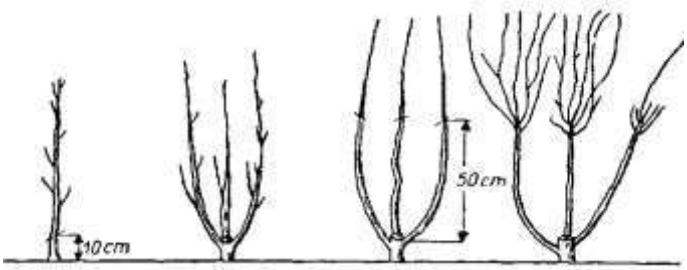

Figure 1. Examples of mulberry shrub trimming (after Kopański 1955).

Figure 2. Seedlings prior to trimming of 1-year old shoots.
Figure 3. Proper trimming of mulberry seedlings.
Figure 4. Shrub-trimmed mulberry seedlings in July.

For the purpose of fruit harvesting it is recommended to cut the main shoot of seedlings at a height of approx. 40-50 cm and in the successive years to leave 2-3 shoots, from which fruits will be collected after several seasons. Thanks to the application of the proposed method large amounts of fruit may be harvested from a relatively low height (fig. 5).

Figure 5. A scheme to cutting mulberry trees for fruit harvesting.

In the first years of plantation cutting operation of 1-year shoots do not pose any major problem, since they do not generate a large biomass volume. It is recommended to collect the cut shoots and dispose of them by chipping to produce fuel material. Nevertheless, on plantations aged several years biomass harvested every year may be as much as 17 t/ha (Łochyńska and Oleszak 2011). Hence the collection of shoots may be extremely time-consuming. The obtained biomass can be baled and used as an additional source of income or a substrate for the production of mushrooms (Moda et al. 2005). It is also recommended to dispose of cut shoots through a passage of a flail mower (mulcher) repeated twice, with shoots being ground to small chips (fig. 6-8). To complete the treatment it is advisable to use a rototiller or a cultivation unit in order to mix the produced chips with soil (fig. 9).

Figure 6. A flail mower chipping cut mulberry shoots.

Figure 7. Ground biomass after the first passage of the mulcher.

Figure 8. Effects of the second passage of a flail mower and shoots lying on the ground before that operation.

Figure 9. A plantation after the agrotechnical procedure is completed (on the left) and before the rototiller operation (on the right).

SOIL CULTIVATION AND FERTILIZATION

Efficiency of leaf harvesting may be considerably improved by applying appropriate tillage operations to prepare the soil for mulberry planting. Tillage facilitates retention of large amounts of water and penetration of air to deeper soil layers, while it also promotes the exchange of gases and minerals and prevents weeding. Tillage operations under white mulberry plantings are performed in the autumn, spring and summer. In the autumn soil has to be ploughed or dug to a depth of 15-20 cm, avoiding root damage. In the spring it is recommended to loosen the soil layer with a rototiller or a cultivation unit in order to reduce water loss through evaporation. Shallow soil loosening has to be repeated 3-4 times throughout the vegetation season to destroy weeds and avoid crust formation, e.g. after heavy rains (fig. 10).

Figure 10. Properly maintained white mulberry plantation.

Fertilization of the white mulberry considerably improves leaf yields, while the content of active compounds increases. Proper soil fertilization improves leaf production by 30-75%. Organic fertilization is necessary on poor and sandy soils. In the autumn fertilization is used on heavier soils, while on lighter soils it is performed in the spring. It is recommended to use compost, manure, peat or green manure. Compost is a highly valuable farm fertilizer exhibiting a rapid and advantageous action. The value of compost is increased by an addition of small amounts of manure. In mulberry plantings compost of good quality is applied at approx. 20-25 t/ha, for 100m hedgerow it is approx. 300-400 kg, while for 1 tree it is 30-40 kg, respectively. After compost is spread the soil should be ploughed or dug at a depth of 10-15 cm. Compost fertilization is applied at every 2-3 years. Manure is used in the autumn or in the spring when it is completely fermented, at every 3-4 years. On a plantation cattle manure is applied at 20-30 t/ha, for a hedgerow it is used at 300-400 kg/100m, while for trees planted in rows it is applied at 30-40 kg/1 tree. It should be covered with a soil layer of 15-20 cm. When establishing manure fertilization doses farmer needs to take into consideration fertilizer quality, since chicken manure contains almost 50% more nitrogen, potassium and phosphorus than cattle manure. The top peat layer may also be used to fertilize mulberry, although this material has to be effectively deacidified. For this purpose a peat heap is sprinkled with lime and mixed thoroughly at every few days. The use of peat requires complementary fertilization, mainly potassium. Green fertilizers should be applied frequently. In mulberry fertilization papilionaceous legumes may be used: beans, broad beans, clover, pea and lupine. At the same time these plants may be utilized as fodder for farm animals.

The application of mineral fertilizers consists mainly in the supplementation of essential elements required to ensure proper vegetation conditions for mulberry, i.e. N, P, K, Ca and Mg. The supplementation of minerals has to be abundant in

successive years after organic fertilization. The dose of the fertilizer is dependent on the type of soil and duration of organic fertilization. The most abundant fertilization should be applied on sandy soils, sterile as a result of rapid mineral leaching.

Nitrogen fertilization is of greatest importance, since it results in an increased number of leaves. In plantings of young shrubs it is recommended to use the dose of pure nitrogen at 20-40 kg/ha, while in older plantations it is 60-80 kg/ha. The dose for 100 m hedgerow needs to be 1-1.5 kg pure nitrogen, which when converted to nitrochalk is approx. 7 kg. After manure is spread the dose of nitrogen needs to be reduced by half.

Phosphorus fertilization enhances the nutritional value of leaves and seed quality. Fertilization is applied in the autumn or early spring. As a rule after manure application phosphorus is not broadcast, while it is recommended after compost fertilization . It is typically recommended to use 200-300 kg/ha mulberry plantation and 300-400 kg/100 m hedgerow.

Potassium fertilization as 60% potassium salt at 150-200 kg/ha or 40% salt with an addition of magnesium and sulphur at 50-65 kg/ha plantation is applied at 3-4 weeks before leaf development.

The total dose of fertilization of mulberry may be divided on two parts. In the first year minerals are applied 100 N: 50 P: 50 K kg/ha. The first dose is applied after 2 months after planting seedlings at the rate 50 N: 50 P: 50 K kg/ha, the second dose after leaf harvest at the rate 50 N kg/ha (Datta 2000).

Liming accelerates the decomposition of organic matter, prevents mineral leaching, improves soil structure and nutrient availability to mulberry shrubs. Soil liming is particularly important in soils with an acid reaction. It is recommended to perform lime spreading in the autumn or early spring, depending on soil reaction at every 2-4 years, maintaining an interval of minimum 6 weeks between liming and manure fertilization. Liming may not be applied simultaneously with organic fertilization, as it results in the release of ammonia and free nitrogen from the soil. Mulberry plantations on light soils need to be fertilized with calcium carbonate in the form of chalk at 200-400 kg/ha, while on heavier soils – calcium oxide lime at 100-200 kg/ha.

All applied organic and mineral fertilizers have to be mixed with soil using a cultivation unit, a rototiller or a rake.

CONCLUSIONS

An established white mulberry plantation made it possible to conduct numerous experiments and trials for a period of 14 years concerning reproduction, tending operations, fertilization and cultivation measures, thanks to which methods of effective plantation management have been developed to provide large yields of leaf, fruit or shoot biomass. The presented fertilization and tending measures for young mulberry trees, as well as cultivation operations considerably shorten tending time and markedly simplify the operation of white mulberry plantations. The recorded results confirm that this plant is well adapted to the Polish climatic conditions and will provide mulberry material for many branches of economy. Presented data are important for farmers planning to establish mulberry plantations or hedgerows for the production of silkworm cocoons or dried herbal material.

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