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Weeds in Forestry and Possibilities of Their Control

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1. Introduction

Thanks to wide inter-row spaces and open canopy in the early phases of establishment, forest nurseries and plantations represent ideal places of floristically rich and diverse weed flora. Weeds have an exceptional capacity of adaptation to environmental conditions because most produce vast quantities of seeds which enable great expansion.

Although the geographic weed distribution and composition depends mainly on climate factors, the vegetation within each climate region is differentiated under the effect of edaphic factors. The soil physical and chemical properties, as well as climate conditions, have the primary significance for both cultivated plants and weeds.

However, all weeds do not have equal significance. When considering weed control attributes, perennial weeds present are far greater challenge due to difficulties employing mechanical means, because perennials are often stimulated to grow and disperse even more intensively. Perennial weed species, such as *Sorghum halepense*, *Convolvulus arvensis*, and *Cynodon dactylon*, have well-developed underground organs and are great problems not only in agriculture, but also in nursery production of forest planting materials.

The problem of forestry weeds came to the fore in recent years as more and more attention has been paid to establishing and restoring forests. In afforested areas, luxuriant development of weed vegetation, can imperil the survival and development of young seedlings. Harmful effects of weeds are reflected not only in the subtraction of basic living conditions such as humidity, light and nutrients already undergo a poor growth and receiving of seedlings.

2. The concept of weeds in forestry

When defining a weed, it should be emphasized that there is no simple and precise definition. Kojic et al., (1996) are of the opinion that weeds are plants growing among cultivated plants and interfere with man's activities; Zekic (1983) stated that weeds are plants growing in places they are not wanted. The concept of a weed is relative in nature, i.e., there is no sharp boundary between weeds and cultivated plants. While in some regions, one plant species is considered a weed, the same species is cultivated in others.

Vajda (1973) considered as forest weeds those plant species interfering with germination and growth of young forest plants and Konstantinovic (1999) those which were unfavourable under certain circumstances in the forest and interfere with forest management. According to Kovacevic (1979) the weeds in forestry are all herbaceous plants, shrubs, and trees which, in forest nurseries, stands, and clear felled areas weaken or prevent the growth and development of cultivated trees.

Evidence of the benefits of weed control for enhanced tree growth is widespread however weeds in forestry are not always harmful. Herbaceous weeds in forest plantations represent food for livestock (DiTomaso, 1997; Papachristou et al., 2009) and dry weights of some weeds are used as bedding for livestock. The fruits of some weeds are edible and weeds while they are somewhere used for human consumption. Some weeds have medicinal properties and are used as medicinal plants (Stepp & Moerman, 2001; Stepp, 2004; Dhole et al., 2009). Weeds prevent soil erosion and can be a shelter for wild animals and birds. However it should be noted that the benefits of weeds significantly less than the damage caused.

3. The properties of weed species

The knowledge gained from the study weed biology under given agro ecological conditions represents the basis in choosing the appropriate measures for their control. Compared to cultivated plants, weedy plants show considerable plasticity in relation to numerous ecological factors. One of the most important weed traits is the expressed adaptation ability. Another important weed trait is the pronounced resistance to unfavourable environmental conditions (drought, moisture, wind etc.). Many weeds are resistant to plant diseases and pests. Also, one of the weed traits is the periodicity of germination. Very often weed seeds do not germinate at once, but rather in different time periods, and it is hard to control weeds simultaneously. In addition, many weeds produce an enormous quantity of seed, which makes it easier for them to spread and expand in space.

4. Propagation of weeds

According to reproduction method, weed plants may be divided into those propagating only sexually, i.e. from seed, and those which are also vegetatively propagated. Sexual weed reproduction results in the formation of seed - reproductive organs by which the weeds are dispersed. All annual weedy plants belong to the group of weeds reproducing only by seed. Under favorable conditions, weeds produce an enormous quantity of seed, even several million of seeds per individual plant. After ripening a great part of the weed seed will end up on the soil surface and subsequently incorporated into the soil by tillage or other means. According to Wilson et al. (1985), under conditions of great weed infestations, some 300 million to 3.5 billion seeds can be found per one hectare of soil. Presence of weed seed in the soil depends on many factors and varies from field to field and region to region (Lutman, 2002).

Vegetative reproduction of perennial weeds represents a very efficient tool for their quick regeneration and distribution. Vegetative reproduction, i.e. regeneration ability of ground vegetative organs, depends first of all on their physiological state. In other words, there is a correlation between intensity of rooting of the rhizome and other ground vegetative organs

and phenophases of plant development which is expressed differently in individual phases. In most cases rooting intensity is very low or completely absent during summer months. The time prior to or at the end of a vegetation period is the most favorable for vegetative regeneration and maximum regeneration ability occurs during spring and autumn (Vrbvnicanin & Kojic, 2000). Regeneration ability of vegetative ground organs depends greatly on environmental factors. Favorable climatic conditions, and in particular, the optimal condition of soil moisture and temperature, affect the regeneration process of vegetative organs.

5. The spread of weeds

Large quantities of seed produced by weeds would not be able to establish and develop in the immediate vicinity of a mother plant. Therefore, the fact that weeds are able to find different ways of quick and efficient seed and fruit distribution is fully justified from a biological point of view (Konstantinovic et al., 2005). In order for weed control to be successful, the means of their distribution must be known. Weeds can be spread by the plant itself, i.e. by self-distribution, and by other factors:

- Wind
- Water
- Animals and
- Man

6. Damage from weeds

Weeds present a large challenge both in agriculture and in forestry. They form a large mass of aboveground and inground organs engaged in a competitive relationship with cultivated plants for light, water and nutritive components in the soil (Kojic et al., 1972). Damages caused to cultivated plants by weeds can be great. According to some opinions, damages caused by weeds are greater than those caused by diseases and pests together (Kojic et al., 1996). Weedy plants grow relatively faster in forest settings and displace young forest plants living space, overshadow and stifle them, and water and nutritive matters are taken at the expense of cultivated plants.

Far less favorable impacts of weeds are found in nursery production. Due to the presence of weeds, nursery plants can experience retardation of growth, chlorosis, reduced resistance to plant diseases and pests, and death of individual parts of branches or crowns; if the weed is abundant, it often leads to drying and deterioration of the entire plant (Zekic, 1983). If weed control in nurseries is lacking, nursery plants of poor quality and fewer total plants are obtained.

7. Distribution of weeds in forestry

Competitive division of weeds in forestry is often made according to the degree of harmfulness of weeds to the trees. According to Vajda (1983) weeds in forestry are classified as either useful or harmful; Konstantinovic (1999) categorizes weeds into useful, harmful, or indifferent. According to this classification:

- Harmful weeds are plants that hinder tree development, and form thick cover
- Indifferent weeds are plants that grow individually, form weak coverage and do not hinder development of cultivated plants
- Useful weeds are plants with medical properties and plants that form fruits

The role of light has been of particular importance for emergence of weeds. In relation to light regime, weeds may be classified into **sciophytes** – plants developing in the shadow in weakly thinned forest stands or in dense forest stands and represent no threat to tree development; **semisciophytes** – semi-shadow plants that develop in thinned stands and can do a lot of harm; and **heliophytes** – plants of open habitats such as clearings, strips, burnt areas, etc., and represent a big threat to renovation and development of trees. There are a number of other weed classifications due to their adaptation to abiotic factors such as water regime, temperature, physico-chemical soil characteristics, etc. during their evolutionary development. However, very important weed classifications in forestry, which would have practical significance from the aspect of weed control, are the following weeds of forest nurseries and weeds of forest plantations and forest stands.

8. The most important weeds in forestry

8.1 Weeds in forest nurseries

Weed flora in forest nurseries differ from those found in forest plantations and forest stands. Given the extent of care measures applied, weeds in forest nurseries are very similar to those found in cultivated crops (Konstantinović, 1999). They are mostly annual and perennial herbaceous weedy species. The most common grass weed species present in the forest nurseries include: *Sorghum halepense*, *Cynodon dactylon*, *Alopecurus myosuroides*, *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Poa annua*, and *Setaria spp.* Dominant broadleaf species include: *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Chenopodium album*, *Cirsium arvense*, *Convolvulus arvensis*, *Erigeron canadensis*, *Datura stramonium*, *Galium aparine*, *Solanum nigrum*, *Sinapis arvensis*, and *Poligonum spp.*

Control of weediness in forest nurseries is very important and quality planting material is the basic prerequisite for success in forest stand establishment. Since weeds are one of the most limiting factors for the success of nursery production, their control should be approached very seriously (Vasic & Konstantinovic, 2008).

8.2 Weeds in forest plantations and forest stands

Weeds in forest plantations and forest stands differ from those in forest nurseries, because, in addition to different care measures applied in plantations and stands, the conditions in habitats also differ. Apart from ferns, herbaceous annual and perennial weeds, woody weeds such as shrubs, bushes, and shoots from the stumps of different tree types may also be present in forest plantations and stands. Woody weeds are very hardy and have a great power of regeneration; it is practically impossible to destroy them completely by mechanical means. The most common weed species present in forest plantations and stands are: *Ambrosia artemisiifolia*, *Amorpha fruticosa*, *Asclepias syriaca*, *Erigeron canadensis*, *Solidago gigantea*, *Sorghum halepense*, *Sambucus nigra*, *Stenactis annua*, *Pteridium aquilinum*, *Rubus caesius* and etc.

9. Weed control in forestry

There are numerous measures and procedures for weed control in forestry today, but, in order to fight weeds successfully, they should consist of different care and control measures. Described below are the six classifications of weed control measures.

9.1 Preventive measures

The main goal of preventive measures is to prevent weed distribution. All measures used to protect any surface from weeds, i.e. to prevent weed seed growth in the field are considered preventive measures (Kovacevic & Momirovic, 2004). Preventive measures in forestry weed control include:

- Control aided by sowing only pure crop seeds, which prevents spreading of weeds over sown surfaces
- Destruction of weeds on non-agricultural areas; weeds that present a constant source of weediness and transportation of seeds to arable lands are developed on such areas
- Prevention of the spread of weed seed by human activities by keeping agricultural and forest machinery and objects clean.
- Allelopathy is a phenomenon, where cultivated plants secrete exudates affecting the suppression of weeds (Pratley et al., 1999). It is manifested in such a way that in the presence of certain plant species, many others are not able to thrive, or are slowly developed (Janjic et al., 2008).

9.2 Mechanical measures

Mechanical measures for combating weeds include basic treatment such as ploughing, disking, tilling and etc. Also regular measures in forest nurseries and plantations are hoeing and farrowing, undertaken during the greatest part of the vegetation period and especially emphasised during the entire spring and in early summer.

One of the ways of suppressing the already growing weeds and preventing their seed dispersal is mowing. Multiple repetitions exhaust the stored substances in the root and the plant is killed. In addition to mowing, one of the methods of weed suppression in forestry is also the pruning of shoots and stump shoots. However, this weed suppression method is relatively expensive due to intense labor and if repeated pruning is required depending on the weed species present (Vasic et al., 2009). Concerns about increasing pesticide use have been major factors for research in physical weed control methods in Europe (Melander et al., 2005).

9.3 Physical measures

Physical weed control measures applied in forestry involve the use of flame and superheated steam. Destruction of weeds by flame can be applied in forest plantations with wider spaces between the rows, provided that the crops are previously protected by metal shields. Burning weeds is carried out on non-productive areas such as forest railways, roads, and canals. Destruction of weeds using steam is applied in forest nurseries in preparation of substrates used for sowing or planting. This is also a form of sterilization which destroys weed seeds in addition to plant diseases and noxious insects. Orloff & Cudney (1993)

believe that the use of flame for the reduction of weeds is the best at the end of growing seasons, because in this way destroy most weed seeds that are dispersed on the soil surface.

9.4 Mulches

The covering of soil with a variety of materials such as straw, stubble, polyethylene films, and others, to prevent the emergence of weeds is utilized on smaller areas, mostly in forest nurseries. Polyethylene films of varying colors and thickness are most often used. This type of weed control is efficient for annual weeds but has no effect on control of many perennial weeds, and can be expensive compared to other methods used to fight weeds.

Many types of mulches have been tried including: sheets of plastic, newspaper, plywood, various thicknesses of bark, sawdust, sand, straw, sprayed-on petroleum resin, and even large plastic buckets. Most have proven to be ineffective, costly or both. Early trials tended to use small, short-lived materials that aided conifer seedling survival but not growth. Compared to other weed control techniques available in previous years, mulches were rather expensive. Current trends are to apply longer-lived, somewhat larger mulches of mostly sheet materials made of reinforced paper, polyester, or polypropylene (McDonald & Helgerson, 1990).

9.5 Biological weed control

Biological measures of weed control are based on the application of natural weed enemies such as insects, fungi, viruses, and bacteria in order to prevent their dissemination, and thus spreading. There are numerous examples of successful biological weed control. Application of pathogenic fungus, *Chondrostereum purpureum*, is used to control beech, yellow birch, red maple, sugar maple, trembling aspen, paper birch, and pin cherry (Wall, 1990). Exotic leaf pathogens, *Phaeoramularia* sp. and *Entyloma ageratinae*, were used for control of *Ageratina adenophora* and *Ageratina riparia* (Morris, 1991) in South Africa. Gordon & Kluge (1991) mentioned that control of *Hypericum perforatum* can be done by using insects *Chrysolina quadrigemina* and *Zeuxidiplosis giardi*. For control of *Acacia longifolia*, the widely spread invasive plant species in Portugal, the bee wasp *Trichilogaster acaciaelongifoliae* was used (Marchante et al., 2011). In those parts of the world where *Eucalyptus* sp. presents a problem the pathogen, *Cryphonectria eucalypti*, may be used for its suppression (Gryzenhout et al., 2003).

Application of biological measures in weed suppression has its limitations, though it has several advantages. Cultivated plants can be protected from some weeds, but not from all of them. It is impossible to destroy weeds completely because the biological agent depends upon the weed for survival; moreover, it is difficult to program biological protection for numerous cultivated plants from weeds with certainty since there are many similarities between weed species and cultivated plants (Konstantinovic, 1999).

9.6. Herbicides

Herbicides are used in forestry to manage tree-species composition, reduce competition from shrubs and herbaceous vegetation, manipulate wildlife habitat, and control invasive exotics (Shepard et al., 2004).

Unlike agriculture, the use of herbicides in forestry began much later and generally the application of herbicides in forestry was based on experiences from intensive agricultural production. The results of research in agriculture are applied in forestry with major or minor delays. Due to the lack of labour, high labour costs, and large areas, producers are more often interested in the use of herbicides. Use of herbicides in forestry decreases weediness, particularly at the initial stages of development of forest nursery plants, when the effect of weeds on plants is the greatest; at the same time, much better economic efficiency in the production process is achieved. Also, possible mechanical damages to the nursery plants can be avoided, and it happens very often that any kind of mechanical treatment is prevented in early stages of plant development due to high soil humidity. Use of herbicides to control competing vegetation in young forests can increase wood volume yields by 50–150% (Guynn et al., 2004).

10. Division of herbicides

According to the type of action herbicides may be divided into the herbicides with contact action and herbicides of translocation. Contact herbicides destroy above ground parts of plant, only the parts of the plant they touch. Translocation or systemic herbicides absorbed by leaves are transferred through the whole plant.

According to the mode of action herbicides may be divided into the total and selective herbicides. Total herbicides kill all plants and selective herbicides kill weeds, and are not harmful to cultivated plants.

According to the time of application herbicides may be divided into the herbicides applied before sowing or planting, herbicides applied after sowing, and before emergence of weeds and cultivated plants and herbicides applied after emergence of weeds and cultivated plants.

11. Mechanisms of action herbicides

For contact herbicides, action is manifested at the site of penetration. Contact herbicides penetrate quickly through cuticle and epidermal cells of plants and the toxic effects on weeds are quickly observed. In systemic herbicides, absorption may occur through the root, stem, and leaf. If an herbicide is absorbed through the roots it can move via the xylem to the above ground parts; more often, it moves to leaves where disturbed respiration and photosynthesis occur. Herbicides absorbed by the leaves and stem cause harmful effects in absorbed plant parts and by spreading via the phloem to reach the root and ground plant organs (rhizomes). Whether the plant will absorb a higher quantity of the herbicide through above ground parts or the root system depends on herbicide application, type of herbicide, and several other factors (Janjic, 2005).

Herbicides exhibit different mechanisms of action. Some herbicides inhibit synthesis of amino acids in plants, and others help the formation of free radicals in plants. Lipid synthesis is the site of herbicide action used to control monocot weeds, and a great number of different herbicides inhibit the process of photosynthesis (Duke, 1990). While some herbicides act only on one process, others act on multiple processes in plants. If only one process in the cell is disturbed, the whole range of processes is affected. Due to that it is difficult to determine the primary herbicide action and consequences.

12. Selectivity of herbicides

Selectivity is a property of herbicides to destroy weeds effectively without harming cultivated plants. Selectivity is not an absolute property of any herbicide. There is a whole range of factors such as morphological, biological and physiological plant traits, chemical composition, and herbicide structure, quantity, mode and time of herbicide application, and translocation of herbicides on which selectivity of some herbicides depend (Kojic & Janjic, 1994; Owen, 1990). Cudney (1996) mentioned that herbicide selectivity is a dynamic process with complex interactions between plant, herbicide and environment.

The main mechanism of herbicide selectivity is the differential metabolism between weeds and crop species, by which susceptible weeds are less able to metabolize selective herbicides (Cole, 1994). The importance of understanding the main stages of differential metabolism-based selectivity derives from the elucidation that plants, to an extent, use cell energy to process and detoxify herbicides (Carvalho et al., 2009).

There is also morphological selectivity based on plant structure. Leaf structure such as vertical and narrow leaf, waxy coat, and a protected vegetation cone contribute to the fact that some grasses are resistant to 2,4-D herbicide. Greater resistance of coniferous species to herbicides compared to broadleaves is also based on leaf structure (Zekic, 1983).

13. Degradation of herbicides

A great part of the total quantity of herbicides applied in agriculture and in forestry is found in the soil. After introduction into soils, several processes affect the vertical and horizontal distribution of the herbicides including transport by water flow, sorption to soil components and various degradation processes. Degradation can involve biotic and abiotic processes, where microbially facilitated biodegradation is especially interesting, as it is a major process in the complete mineralisation of compounds to harmless inorganic products (Alexander, 1981; Kojic & Janjic, 1994).

Decomposition of herbicides in the soil is a complex process taking place in several stages such as photodegradation, chemical degradation, and microbiological degradation.

Photodegradation is means that some herbicide molecules such as trifluralin, dinitroaniline are degraded by the influence of ultraviolet rays, and these herbicides should be incorporated into soil after application (Konstantinovic, 1999). Chemical degradation of herbicides in the soil is done through processes of oxidation, hydrolisis, hidratation and reduction during which the herbicides are completely or partly degraded. Microbial degradation plays an important role in herbicide breakdown, and of their toxic material found in soil. Herbicides not only influence the activity of microorganisms, but the fate of herbicide in the soil depends on the activity of microorganisms (Janjc, 1996). Ability of microorganisms to carry out herbicide biodegradation depends on the type af applied herbicide (Govedarica & Mrkovacki, 1993; Dordevic et al., 1994; Milosevic & Govedarica 2000), herbicide chemical properties (Poppell et al., 2002; Martins et al., 2001), applied herbicide concentrations (Gigliotti & Allievi, 2001), and great number of biotic and abiotic factors.

14. The toxicity of herbicides

Toxicity is the capacity of a substance to harm or disturb the health of an organism (Sovljanski, 2003). Toxic effects may be immediate (acute) or accumulative (chronic), depending upon the exposure duration, the dose, and the herbicide. The toxicity of a substance varies with the animal species, age, sex, and nutritional status and with the route of exposure – through the stomach (orally), the lungs (by inhalation), or the skin (dermally). The skin and eyes are also subject to irritation caused by chemicals.

A common way to document toxicity is by oral LD₅₀ values. LD₅₀ is the amount of chemical required to provide a “lethal dose” to 50% of the test population. LD₅₀ is measured in mg of chemical administered per kg of body weight (Fishel et al., 2006). Toxicity tests are conducted on experimental animals, such as white rats, mice, and rabbits. Due to different ways of herbicide action when estimating its toxicity the whole range of data should be known and therefore it is difficult to express herbicide toxicity (Janjic, 2005).

15. Impact of herbicides on the environment

The impact of herbicides on the environment (water, soil, biodiversity, etc.) may have diverse effects depending on the whole range of factors and, initially, on the environment in which it is found after application. In general, herbicides most commonly used for vegetation management in forestry (glyphosate, triclopyr, imazapyr, sulfometuron and etc.) degrade quickly once they enter the environment and thus are neither persistent nor bioaccumulative (Tatum, 2004). Forest herbicides persist short term in the environment, and have few toxic effects when operationally applied following herbicide labels (Guynn et al., 2004). Single applications of forestry herbicides at stand initiation have minor and temporary impacts on plant communities and wildlife habitat conditions (Miller & Miller, 2004). Studies carried out on the effect of herbicides hexazinone fosamine ammonium and glyphosate in forestry have revealed that these herbicides have minimal effects on soil microorganisms and exhibit little or no potential for bioaccumulation (Ghassemi et al., 1982). If herbicides are properly used, current research indicates that the negative effects on wildlife usually are short-term and that herbicides can be used to meet wildlife habitat objectives (Wagner et al., 2004).

16. Possibilities of weed control in forest nurseries

16.1 Mechanical weed control

In addition to irrigation, fertilization, and pruning of branches and tender shoots, hoeing and dusting are also very significant care measures in forest nurseries for production of planting material. Hoeing and dusting are regular measures applied during most of the vegetation period, and are particularly pronounced during the spring and at the beginning of summer. The purpose and objective of hoeing and dusting are, in addition to destruction of weeds, the maintenance of such soil structure that provides the optimum water-air regime of soil layers in which the root system develops (Roncovic et al., 2002).

The number of hoeing and farrowing applications required depends on the soil preparation, climate conditions, and on weed emergence. Markovic et al., (1995) claimed that first hoeing

is a very significant measure that must be paid attention to particularly around cuttings and roots in order to avoid damages of buds and young shoots.

However mechanical measures have no long lasting effect in weed control due to relatively fast regeneration of weed flora (Table 1). Combined chemical and mechanical measures applied in forest nurseries are very effective in weed control. Use of herbicides decrease weediness in the early stages of development of cultivated plants when negative influences of weeds are the most dangerous. Mechanical injuries of nursery plants can be avoided in that way, and very often they are prevented due to high soil moisture. Mechanical measures are aimed at maintaining soil water-air regime and control of weeds that may subsequently have emerged.

Weed types	Treatment alternatives	Cost Euro/ha	Effectiveness	Potential Environmental Impacts
Perennial broadleaf and grass weeds	herbicides	50 - 100	Very effective	They can be potential polluters depending on the applied herbicide and the environment in which the herbicide occurs (water, soil)
	cutting	100 - 200	Not effective	No adverse effect on the environment
	cultivation	150 - 190	Effectiveness varies with weed and site	No adverse effect on the environment
	mulches	600 - 820	Only effective on annual weeds	No adverse effect on the environment
Annual broadleaf and grass weeds	herbicides	30 - 100	Very effective	They can be potential polluters depending on the applied herbicide and the environment in which the herbicide occurs (water, soil)
	cutting	100 - 200	Only effective on annual weeds	No adverse effect on the environment
	cultivation	150 - 190	Effectiveness varies with weed and site Very effective	No adverse effect on the environment
	mulches	600 - 820	Only effective on annual weeds	No adverse effect on the environment

Weed types	Treatment alternatives	Cost Euro/ha	Effectiveness	Potential Environmental Impacts
Woody weeds	herbicides	60 - 120	Very effective	They can be potential polluters depending on the applied herbicide and the environment in which the herbicide occurs (water, soil)
	cutting	100 - 200	Not effective	No adverse effect on the environment
Bracken	herbicides	60 - 120	Very effective	They can be potential polluters depending on the applied herbicide and the environment in which the herbicide occurs (water, soil)
	cutting	100 - 200	Weakness effect	No adverse effect on the environment

Table 1. Comments on control methods adopted and impacts in forestry

16.2 Application of herbicides

More attention is being paid to the application of herbicides as one of the control measures against weeds in forest nurseries. Due to the lack of labour, high labour costs, and large areas, the application of herbicides might be considered as the only possible way of weed control (Table 1).

When choosing herbicides, it is important to take care of several factors such as: weed composition, range of herbicide action, phenophase of development of cultivated plants, and time and manner of herbicide application.

16.2.1 Herbicides that can be used in forest nurseries

Application of herbicides in forest nurseries is that the biological and economic point of view is fully justified. Doses of herbicide application are low and there is no danger to wildlife, crops and watercourses (Zekic, 1979). For weed control in nurseries is necessary to provide a lot of labour and for mitigate this problem and increase the productivity application of herbicide is necessary. Chemical weed control in forest nurseries represents a complex job. In order to obtain the expected effect should take into account number of factors such as composition of the weed, the spectrum of action of herbicides, soil type, rainfall, temperature and etc. Herbicides that can be used in nursery production of some forest tree species are as follows:

Dasomet - is applied 2 - 5 weeks prior to sowing or planting in quantity of 30 - 60 g/m² incorporated into the soil up to the depth of 8 - 10 cm. It is used for soil treatment in nurseries before sowing or planting.

Trifluralin - registered rate is 1,5 - 2,5 l/ha depending on soil with mandatory incorporation at a depth of 5 - 8 cm. It is used for soil treatment in nurseries before sowing or planting.

Azafenidin - is applied in quantity of 100 - 125 g/ha after sowing or planting, and before emergence of cultivated plants. It is used in production of poplar (*Populus euramericana*, *Populus deltoides*.) for control of a great number of broadleaf weeds (Photo 1).

Acetochlor - is applied in quantity of 2 l/ha after sowing or planting, and before emergence of cultivated plants. It is used in production of poplar (*Populus euramericana*, *Populus deltoides*), oak (*Quercus robur*), and black locust (*Robinia pseudoacacia*) nursery plants for control of a great number of grass and broad leaved weeds.

Dimethenamid - is applied in quantity of 1,2 - 1,4 l/ha after sowing or planting, and before emergence of cultivated plants. It is used in production of poplar (*Populus euramericana*, *Populus deltoides*), oak (*Quercus robur*), and black locust (*Robinia pseudoacacia*) nursery plants for control of great number of grass and broadleaf weeds.

Linuron - is used for soil treatment after sowing or planting, and before emergence of cultivated plants. It is applied in quantity of 2 l/ha in production of poplar (*Populus euramericana*, *Populus deltoides*), willow (*Salix* sp.) and oak (*Quercus robur*).



Photo 1. Efficiency of combination of herbicides Acetochlor (Relay plus) and Azafenidin (Evolus 80-WG) in nursery production of poplar (*Populus euramericana*, *Populus deltoides*)

Metribuzin - registered rate is 0,500 - 0,750 kg/ha after planting, and before emergence of poplars (*Populus euramericana*, *Populus deltoides*) and weeds. It is used for control with a greater number of annual broadleaved weeds. If applied on sandy soil with a lighter mechanical composition, it can have phytotoxic effects on poplar seedling (Photo 2).

Promethrin - is used for soil treatment after sowing or planting, and before emergence of cultivated plants and weeds. It is applied in quantity of 2 l/ha in production of poplar (*Populus euramericana*, *Populus deltoides*) and willow (*Salix* sp.) nursery plants (Photo 3).



Photo 2. Phytotoxic effect of n poplar seedling (*Populus euramericana*, *Populus deltoides*)



Photo 3. Efficiency of herbicides in nursery production of poplar plants (*Populus euramericana*, *Populus deltoides*)

Pendimethalin – is used for control of many annual grass weeds in production of poplar (*Populus euramericana*, *Populus deltoides*) nursery plants. It is applied after sowing or planting in quantity of 4 – 6 l/ha depending on soil.



Photo 4. Control plot

S-metolachlor – registered rate is 1,2 – 1,5 l/ha after sowing or planting, and before emergence of weeds and cultivated plants. It is used for control of annual grass and broadleaf weeds in production of poplar (*Populus euramericana*, *Populus deltoides*), black locust (*Robinia pseudoacacia*), willow (*Salix* sp.) and oak (*Quercus robur*) nursery plants.

Oxyfluorfen – registered rate is 1 l/ha after sowing or planting, and before emergence of cultivated plants. It is used in production of poplar (*Populus euramericana*, *Populus deltoides*) nursery plants for control of large number of grass and broadleaf weeds.

Cycloxydim – is used for foliar control of annual and perennial grass weeds in production of poplar (*Populus euramericana*, *Populus deltoides*), black locust (*Robinia pseudoacacia*), oak (*Quercus robur*), maple tree (*Acer* sp.) and bee tree (*Evodia hupehensis*) nursery plants. It is applied in quantity of 3 l/ha at the stage of intensive weeds growth.

Glyphosate – is used for total control of emerged weeds on areas planned for sowing or planting, and on areas where sowing and planting have already been performed, and prior to appearance of cultivated plants or nursery plants. It is applied in quantity of 2 – 12 l/ha with water consumption of 200-400 l/ha.

Glufosinate - ammonium – is used as non-selective, contact herbicide for control of weeds on areas planned for sowing or planting, and on areas where sowing or planting have already been done, and before to the appearance of cultivated or nursery plants. It is applied in quantity of 4 -7,5 l/ha with water consumption of 400-600 l/ha.

Hexazinone – registered rate is 1,5 – 2 kg/ha in pine germination chambers 1,5 to 2 months after sowing and 2 – 3 kg/ha in nurseries. Pines are highly resistant to herbicide hexazinone, except *Pinus strobus* and *Pinus contorta*. Brown, necrotic spots appear on Norway spruce and

larch is completely destroyed. It has a large range of action, long-lasting, so the soil remains clear throughout vegetation period.

Fluazifop-p-butyl – is used for foliar control of annual and perennial grass weeds in production of willow, poplar, oak, maple tree, birch, and beech. It is applied in quantity of 1,3 l/ha when weeds are at intensive growth phase.

Haloxifop-p-methyl – is used for foliar control of annual and perennial grass weeds in production of poplar, acacia, oak and maple tree nursery plants. It is applied in quantity of 1 – 1,5 l/ha when weeds are at intensive growth phase.

Imazethapyr – is used in production of acacia nursery plants. It is applied at a quantity of 1 l/ha after black locust emergence and controls a great number of grass and broadleaved weeds.

Diquat – is used for total control of emerged weeds on areas planed for sowing or planting, and on areas where sowing or planting have already been done, and before to the appearance of cultivated or nursery plants. It is applied in a quantity of 4 – 6 l/ha.

Quizalofop-p-ethyl – is used for foliar control of annual and perennial grass weeds in production of willow, poplar, oak, maple tree, birch, and beech nursery plants. It is applied in a quantity of 1 – 1,5 l/ha at the intensive growth phase.

17. Possibilities of weed control in forest plantations

17.1 Mechanical weed control

Control of weed vegetation in forest stands is performed by mowing, cutting, pulling, etc. However, this way of weed control today is slow, inefficient and expensive and it must be repeated. Weed control between the rows is most often by mowing or by weed cutters, and within the row, or around the plants weed control is by application of herbicides.

17.2 Application of herbicides

Due to the presence of both herbaceous and woody weeds, application of herbicides in forest stands is of great significance. Woody weeds are very resistant and have great power of regeneration, therefore difficult to kill completely by mechanical means. It is very important to perform weed control in stands in a timely manner (at the stage of intensive growth) and in the right manner in order to use minimal herbicides inputs with effective results. Costs of weed control in stands by application of herbicides are much lower since reapplications are generally not required and it can be performed with less labour. Weed control in stands can be performed over the entire surface (broadcast application), within rows, or just around the nursery plants. The aim of weed control in forest stands is not complete destruction of weed flora, but prevention of competitive relationships with nursery plants and termination of growth.

However, their application is sometimes impossible in some systems because, very often, agricultural crops such as maize, soya, wheat, etc. are sown between the rows in order to use that space (Photo 5 and 6). In that case, selective herbicides for use in maize and efficient for control of weeds present in stand should be used. The most often used herbicides are those based on fluroxypyr or mesotrione.



Photo 5. Inter-row sown corn in the poplar plantation



Photo 6. Inter-row sown soybeans in the poplar plantation

17.2.1 Herbicides that can be used for weed control in forest plantations

Weed control in forest plantations should be carried out until the moment when the seedlings provided normal development and growth according when seedlings grow beyond the zone of herbaceous weeds and shoots from the stumps. This moment the performance of various plantations in the different age because it depends on many factors such as species and age of seedlings, soil type, ground preparation prior to afforestation and etc. Weed control in forest plantations is not intended to completely destroy weed seedlings than the release from weed competition according to stop weed growth and development. Application of herbicides in forest plantations can be done on the whole surface in rows or around trees. We should take into account that the applied herbicides do not reach the leaves of seedlings. For this purpose they may use the following herbicides:

Glyphosate – is used for complete weed control during the stage of intensive growth and concentration of 2-3%. Its efficacy on weeds is high due to good translocation into root and rhizomes. Side shoots, if present, should be removed prior to treatment with glyphosate because the preparations based on glyphosate should not reach the leaves of nursery plants (Photo 7 and 8). Glyphosate is used for treating stumps in order to prevent emergence of shoots from stumps. Concentration of 10-15% is applied immediately after cutting, but the treatment may be applied until shoots appear from May through October (Photo 9 and 10).



Photo 7. Efficiency of herbicide glyphosate in poplar plantation



Photo 8. Inter-row application of herbicide glyphosate in the plantation

Glufosinate - ammonium – is used as non-selective, contact herbicide for control of weeds in forest plantations. It is applied in quantity of 4 -7,5 l/ha with water consumption of 400-600 l/ha.

Triclopyr – is used for oak stump shoots control in the ration of 1:5 or 1:10 for other broadleaved species. The best way is to treat stumps immediately after cutting, but it can be done until the shoots emerge. It can be performed during entire year, except during freezing.



Photo 9. Treated stumps by glyphosate



Photo 10. Non treated stumps

18. Possibilities of weed control in the natural and artificial regeneration of pedunculate oak forest

In addition to harmful insects and diseases, weed vegetation represents a great problem in renovated pedunculate oak (*Quercus robur* L.) forests. Presence of weeds and great number of shrubby species per area unit is a basic limiting factor for continual spontaneous rejuvenation and offspring survival (Bobinac et al., 1991). Natural renovation is often poor or completely missing due to the presence of a great number of weeds. Due to the impossibility of preserving seedlings, and formation of quality offspring as well as the

decline and slow development, the weed vegetation in young pedunculate oak forest should be suppressed. Prior to acorn planting it is important to perform the site preparation in order to provide the most favourable conditions for oak development. The acorn is planted in the autumn or spring in the soil prepared for the reception of the seed. If renovating surfaces are prepared prior to sowing then the problems with weeds encountered later when maintaining the surfaces are much smaller. But despite the completion of site preparation in the first and the second year after renovation, the occurrence of some weeds that emerged subsequently or were not affected by the preparation treatment before planting, may be expected.

18.1 Mechanical weed control

Removal of debris in the form of wood chips obtained by stump grinding is done completely or partially by collecting heaps, and spreading them on skid trails and then burning. Suppression of shrubs and shoots from the stumps may be accomplished manually by cutting with scythes, scissors, axes and etc. However, such weed suppression is inefficient and expensive, and is being replaced by faster and more efficient ways of suppression.

18.2 Application of herbicides

The most often encountered problem in pedunculate oak forest renovation is *Rubus caesius* L. (European dewberry) forming impenetrable thickets. Besides blackberry, *Crataegus monogyna*, *C.oxycantha*, and *Rosa arvensis* may also pose a problem although significantly smaller. Also, if the shoots from stumps are not suppressed they can reach the height of up to 1,5 m, and blackberry and other weeds form thick cover, then the chemical control is difficult to perform due to impenetrability and requires a much higher expenditure of funds.



Photo 11. Application herbicides glyphosate after sowing and before emergence of cultivated plants (*Quercus robur*)



Photo 12. Emergence of oak plants after application of total herbicide

18.3 Herbicides that can be used for weed control in regeneration of pedunculate oak (*Quercus robur* L.) forest

To work in weed control in regeneration of pedunculate oak (*Quercus robur* L.) forest were successful among series of measures that are applied herbicide application is necessary. Herbicides that can be used for weed control in regeneration of pedunculate oak (*Quercus robur* L.) forest as:

Cycloxydim - is used for foliar control of annual and perennial grass weeds. It is applied in quantity of 3 l/ha or applied twice at half-dosage (1,5 + 1,5 l/ha) when weeds are at the intensive growth stage.

Clopyralid - is used for control of a great number of broad-leaved weed species such as *Cirsium arvense*, *Ambrosia artemisifolia*, *Solanum nigrum*, *Erigeron canadensis* and etc. in renovated pedunculate oak forests. It causes transient symptoms of phytotoxicity in annual pedunculate oak plants (creating "a spoon like appearance"), while it is selective toward two-, and three-year oak plants, and causes no symptoms of phytotoxicity. It is applied in quantity of 1 l/ha with water consumption of 300 l/ha.

Nicosulfuron - is selective for pedunculate oak plants. It is used for control of a great number of annual broad leaf weeds, and for some perennial weeds. It is applied in the quantity of 1 - 1,2 l/ha.

Fluazifop-p-butyl - is used for foliar control of annual and perennial grass weeds in renovated pedunculate oak trees. It is applied in the quantity of 1,3 l/ha at the stage of intensive weed growth.

Glyphosate – is used for total control of weeds emerged on areas planed for sowing or planting, and on areas where sowing or planting have already been done, and before appearance of cultivated or nursery plants (Photo 11 and 12). It is applied in quantity of 2 – 12 l/ha, with water consumption of 200-400 l/ha.

Glufosinate - ammonium – is used as a nonselective, contact herbicide for weed control on areas planed for sowing or planting, and on areas where sowing or planting have already been done, and prior to appearance of cultivated or nursery plants. It is applied in quantity of 4 – 7,5 l/ha, with water consumption of 400-600 l/ha.



Photo 13. Efficiency of herbicides in artificial regeneration of pedunculate oak forest



Photo 14. Efficiency of herbicide clopyralid (Lontrel-100) in regeneration of pedunculate oak forest

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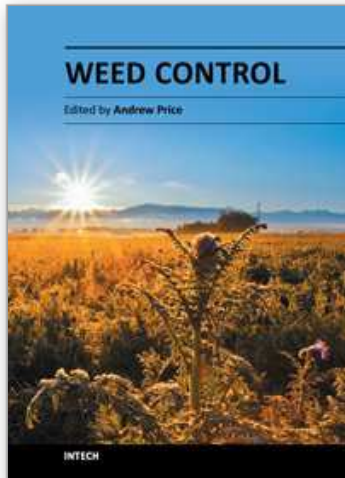
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Crop loss due to weeds has challenged agricultural managers since man began to develop the first farming systems. In the past century, however, much progress has been made to reduce weed interference in crop settings through effective yet mostly non-sustainable weed control strategies. With the commercial introduction of herbicides during the mid-1900's, advancements in chemical weed control tactics have provided efficient suppression of a broad range of weed species for most agricultural practices. Currently, with the necessity to design effective sustainable weed management systems, research has been pushing new frontiers on investigating integrated weed management options including chemical, mechanical as well as cultural practices. Author contributions to Weed Science present significant topics of research that examine a number of options that can be utilized to develop successful and sustainable weed management systems for many areas of crop production

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