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REACTION OF POPLAR SEEDLINGS AFTER SELECTIVE HERBICIDES TREATMENT

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Abstract

The reaction after treatment with selective herbicides was carried out in a nursery plot for production of one-year-old poplar saplings from the type 0/1 from the cultivars 'I-214' and 'Vernirubens'. Water solutions of the 4 herbicides (H1–H4) with a concentration 5 ml.l^{-1} and a control variant were tested. Treatments were carried out in five terms: May, June, July, August and September. Final measurements were carried out after the growing season. The estimation of the influence of each herbicide was done after the following indices: survival, height and diameter of the stem; thickness and number of first grade roots; relative moisture of wood of poplar saplings. The results showed that tested herbicides do not influence on the survival of saplings with the exception of a negative influence on cultivar 'Vernirubens', caused by the herbicide H2. Saplings of cultivar 'I-214' have faster growth in height than cultivar 'Vernirubens'. Tested cultivars show specific reaction to applied herbicides and best tolerance to H3 (350 g.l^{-1} Butachlor + 350 g.l^{-1} Propanil). Herbicides H1 (150 g.l^{-1} Fluazifop-P-butyl) and H4 (240 g.l^{-1} Oxyfluorfen) oppress less the growth of saplings at both cultivars, compared to the outlined depressive effect of the herbicide H2 (240 g.l^{-1} Clethodim). As most suitable was determined the herbicide H3. In the course of production, weed control could be carried out with the help of this herbicide during all phoenophases of the development of saplings.

Key words: cv. I-214, cv. Vernirubens, poplar seedlings, *P.* × *canadensis*, reaction, selective herbicides.

Introduction

Traditionally in the forestry practice in the moderate climate zone countries, including Bulgaria, poplar plantations have a significant share in afforestations. The interest to poplar growing is determined by the fast growth of poplars, their high productivity in short rotation and the constant big demand of timber by consumers. The sites in forest territories of Bulgaria, suitable for poplar-growing, are about 26,000 ha. Predominantly, approved cultivars of Canadian poplar hybrids (*Populus* × *canadensis* Moench) are used. The biggest share is of cv. I-214 – about 44 %, and the share of the cultivars 'Bachelieri', 'CB-7', 'I-45/51', 'Vernirubens', 'Agate F', 'MC', etc. is 5–8 % each. During the last 8 years (2012–2019), 5000–8000 dka of poplar plantations were established in Bulgaria and their share is average 40 % of the totally afforested areas (operational information from the Executive Forest Agency for the period 2012–

2019). The data show a trend of increasing, which determines constant necessity of poplar saplings and optimisation of their production.

Basic problem in the production of poplar saplings is the phytosanitary status of production areas and especially of weeds. Weeds are determined as one of the most limiting factors for the success of nursery production (Vasic and Konstantinovic 2008, Vasic et al. 2015). Bigger distance between planting rows and bigger access of light in the initial stage of development of saplings predispose to large-scale development of weeds (Vasic et al. 2007). Poplars are particularly demanding of both moisture and rich soils. Weeds do not overgrow saplings but compete them predominantly for water and nutrients (Kauter et al. 2003, Wagner et al. 2006, Kabba et al. 2007, Tobisch 2007). Some authors draw the attention to the most significant period of maximal negative influence of weeds and determine it as critical point. They also determine the critical period for weed control (Knezevic et al. 2002, Bukun 2004). The weed control is also carried out according to economic indices of the obtained income and expenses for weed control. The point of maximal loss of yield during the critical period is determined as critical point (Otto et al. 2009). The knowledge about losses caused by weeds in the production is important for the timely control (Dorado et al. 2009). These losses are estimated as bigger towards losses caused by insect pests and diseases. Hybrid poplars are very sensitive to the competition of other vegetation, especially during the first growing period (Buhler et al. 1998, Coll et al. 2007). It is determined that weeds show most unfavourable influence in the initial phase after rooting of poplar cuttings (Anselmi and Giorcelli 1983, Kauter et al. 2003, Dhiman and Gandhi 2011). In the presence of strong weeding during this period, the growth is depressed and dyeing of saplings is also observed. Thus towards the end of the growing period the quality and quantity of production are unsatisfactory. Broeckx et al. (2012) point out that only when proper weed control is carried out it could be expected that losses should be fewer than 20 %.

During an experiment with weed control through various methods, including combinations with paddy straw mulch and plastic mulch strips, Kaur et al. (2016, 2018) determine that the effect of elimination of weeds with preparations (Pendimethalin with 1 kg·ha^{-1} and Alachlor with 2.5 kg·ha^{-1}) for improving the *Populus deltoides* saplings growth is expressed through bigger height (11–19 %) and diameter (20–28 %) growth. The results from the best variants are similar to the control one through mechanical manual weeding.

Thomas et al. (2001) compare the use of opaque polyethylene mats and glyphosate treatment (applied at a rate of 2.1 kg active ingredient per ha in midsummer of the second and third growing seasons). The experiment was carried out during four growing seasons. The authors report that the opaque polyethylene mats significantly improved poplar height growth only for the first growing season. After the four growing seasons, hybrid poplars treated with glyphosate were significantly taller than those in either the mat or control treated plots. Diameter at breast height was also significantly greater in the herbicide treated plots than in either the mat or control treated plots. Total volume was also significantly greater in herbicide plots than in either the mat or control plots.

Hansen and Netzer (1985) report that weeds do not cause saplings loss but influence negatively on their growth proportionally to the competition level of weeds. Depressive influence of weeds is determined, compared to variants with manual weeding, and the height of poplar saplings is less with 8–15 %, diameter – with 6–18 % and above-ground biomass – with 21–58 %. Similar results are presented by Marino and Gross (1998) and Sixto et al. (2001).

Recommendations for herbicides using in nursery production are given by James et al. (2003). Oxyfluorfen, Simazine and Izoxaben are suitable before the occurrence of the weeds, efficient against broad-leaved weeds. Oryzalin, Pendimethalin and Prodiamin are efficient in the control with grasses and some small-seed broadleaved weeds. Fluazifop-butyl, Sethoksidym and Clethodim are selective herbicides to be used after germination, used for grasses control. Glyphosate, Paraquat and Glufosinate are non-selective herbicides for after germination, used for wide-various weed control. Bentazon, Halosulfuron-methyl and Imazaquin are efficient after germination. Metolachlor is pointed out as especially designed for nurseries. Chloroacetanilides are used for preliminary treatment against annual grasses and some perennial broadleaved weeds (Soltani et al. 2011). Metribuzin is Triasin herbicide, which inhibits photosynthesis (Flores-Maya et al. 2005). This herbicide could be applied in control with annual grasses and broadleaved weeds (Majumdar and Singh 2007). Especially for poplar nurseries, as efficient and with good selectivity towards non-rooted cuttings, herbicides Tiazopir (Sixto et al. 1999) and Oxyfluorfen (Sixto et al. 2001) are recommended. For the systematic herbicide Glyphosate it is mentioned that it kills plants of many species through its translocation in plants and therefore its application should be very careful to avoid losses on saplings (Dhiman and Gandhi 2011).

The selection and application of herbicides is complicated task because it is related to many factors – the herbicide chemical composition and structure, quantity, method and time of application, climatic and meteorological conditions, soil type (Prasse 1985). The humus content in soil is of particular importance. It has direct effect on the herbicide activity due to its adsorption ability. The content of colloid particles decreases the herbicide activity due to the big tendency of herbicides to joining (Spark and Swift 2002).

The mechanical weed control is expensive, slow and low-efficient. The manual trenching between the rows is the mostly applied method for weed control, and elimination of weeds around the plants in the rows is difficult. There are muddy periods caused by rains or watering and the conditions do not allow in-time mechanical weeding. These problems demand application of chemical tools for in-time and efficient weed control (Kaur 2016).

Berthelot and Bonduelle (1993) point out that the expenses for treatment with herbicides are considerably less than those for the traditional weeding. Experiments of Dhiman and Gandhi (2011) for integrated control through herbicides, including straw mulch and polyethylene, have shown that the expenses for chemical weed control are 6–7 times less compared to the mechanical way.

The mechanical weed control in forest nurseries in Bulgaria is also basic production expense (Vatov and Zahov 1980), and meanwhile the capabilities of herbicides for production optimisation are not revealed (Iliev 2007, Iliev and Iliev 2010). Investigations are directed mainly to their capabilities for application in agriculture (Keremidchiev et al. 1980, Abrahamson

1987). Important reason to rely more on herbicides is also the still unsolved problem with the manpower.

Experiments with application of herbicides in forestry in Bulgaria have been carried out for the first time in 1957 (Vatov and Zahov 1981). Their more organised practical application is carried out since 1978, after the development of a Programme for extension of the application of herbicides in forestry (Vatov and Zahov 1980). Results from application of herbicides in forest nurseries and plantations have been also published by Garelkov et al. (1962), Vatov and Zahov (1980, 1981) and Bochev (1985, 1988). More recent studies on the application of selective herbicides in forest nurseries are carried out by Iliev (2007), Iliev and Iliev (2010) and Iliev et al. (2013). For the time being, there is no published information about application of herbicides in the production of poplar saplings.

It is considered that between 50 and 400 man-hours per 1 dka are necessary for manual weeding in forest nurseries (Abrahamson 1987, South 1994). The use of selective herbicides can reduce the necessary time for manual weeding with 80–87 % (Abrahamson 1987).

The aim of the investigation is to determine the reaction of poplar saplings to the application of some selective herbicides for production improvement.

Object and method of work

The study was carried out in Dragor nursery, State Forest Enterprise Pazardzhik, in the central part of South Bulgaria (42°41′52" N 23°19′18" E) at an altitude 204 m a.s.l. The average annual temperature is $T_{av.}$ = 11.7 °C. The average annual amount of precipitations is W_{ann} = 568 mm. The soil in the nursery is Mollic Fluvisols, very deep, with clayey-sandy mechanical composition in the surface layer 0–35 cm. The overall moisture capacity is 29.75 %. It is very poorly stocked with humus and poor of nitrogen. The stock of assimilate phosphorus is poor, and the stock with assimilate potassium is very good. The soil reaction on the surface soil layer (0–35 cm) is neutral.

Experiments were carried out in a plot for production of one-year-old poplar saplings of the type 0/1 from *P.* × *canadensis* cv. I-214 and cv. Vernirubens.

In October the sample plot was ploughed in a depth 30–35 cm, and in the beginning of March next spring the soil was tillaged in a depth 10–12 cm. The shoots used for cuttings were obtained in the beginning of February. The cuttings were cut into 22 cm long pieces with diameter of the thin edge not less than 0.8 cm, and of the thick edge not more than 1.8 cm. The cuttings were stored in a fridge camera at a temperature 2 °C and relative air humidity 90 %. The planting was carried out in the middle of March. The planting scheme is two-row with 1.85 m between couples of rows and 0.50 m between rows. The distance between cuttings in the row is 0.30 m.

The experimental variants include 3 repetitions, 30 saplings each. The repetitions were developed consequently along the length of the double rows

Water solutions of the herbicides H1 (150 $g.l^{-1}$ Fluazifop-P-butyl), H2 (240 $g.l^{-1}$ Clethodim), H3 (350 $g.l^{-1}$ Butachlor + 350 $g.l^{-1}$ Propanil) and H4 (240 $g.l^{-1}$ Oxyfluorfen) with concentration 5 $ml.l^{-1}$ and control variant were tested. The concentration is selected according to the directions of the producers and the maximal high value among the recommended ones was applied.

Treatments were carried out every month in 5 terms: from May to September. The moment of spraying is in the beginning of each month. Within the same terms, the heights of saplings from control variants were measured, and final measurements were carried out in the beginning of November after the end of the growing season.

The estimation of the effect of the herbicides was carried out according to the indices: survival; rate of growth of saplings; height and diameter of the stem; thickness and number of first grade roots and relative moisture of wood of poplar saplings.

For the determination of the relative moisture of the saplings, 3 saplings with average dimensions from each variant were taken out with their root system after the end of the growing season, cut into pieces and dried at a temperature 105 ±2 °C until they reach constant weight at two consequent accounts.

The statistical analysis of results was carried out with the help of SPSS 11. The mean and standard error were estimated by One-Way ANOVA followed by a post hoc LSD test at $p \leq 0.05$.

Results

All applied herbicides brought to sustainable suppression of the grass vegetation and to experimental variants clean of weeds.

The survival of saplings in both investigated cultivars was synonymous from statistical point of view, within the range from 84 to 100 % (Table 1). Proved lower percentage of survival (62 %) was obtained only for cv. Vernirubens, variant H2.

Table 1. Influence of selective herbicides on the survival of the saplings.

Variant/ herbicide	Survival, %	
	'I-214'	'Vernirubens'
Control	86.67 ±3.84 b	94.45 ±2.22 b
H1	100.00 ±0.00 b	87.78 ±6.19 b
H2	84.44 ±7.28 b	62.22 ±14.19 a
H3	100.00 ±0.00 b	97.78 ±1.11 b
H4	94.43 ±5.56 b	92.22 ±4.01 b

Note: The mean and standard error within a column followed by the same letter were not significantly different.

As early as the initial treatment, the two cultivars reacted with various growth in height depending on the applied herbicides. For cv. I-214 (Table 2) with biggest height growth, statistically different from all other variants, were the saplings from the control – average 229 cm. Best effect on the growth in the treated variants was obtained applying H3, when the average height of the saplings reached 205 cm.

Table 2. Influence of selective herbicides on the growth of cv. I-214.

Variant / herbicide	Stem height, cm	Thickness of saplings in the basis of the stem, mm	Thickness of roots, mm	Av. number of roots 1-st grade
Control	229.16 ±8.12 g	21.45 ±0.67 f	4.30 ±0.17 e	29.11 ±2.52 d
H1	161.01 ±5.60 d	18.18 ±0.63 e	2.98 ±0.19 b	19.50 ±2.41 bc
H2	99.04 ±3.88 b	12.80 ±0.38 b	2.53 ±0.13 ab	16.22 ±1.99 b
H3	205.43 ±6.51 f	20.12 ±0.66 f	3.68 ±0.18 cd	24.22 ±2.49 cd
H4	173.78 ±5.07 de	15.71 ±0.45 d	2.21 ±0.14 a	21.33 ±1.98 bc

Note: The mean and standard error within a column followed by the same letter were not significantly different.

At cv. Vernirubens, however, saplings treated with H3 reached bigger average height – 179 cm compared to the control – 146 cm (Table 3).

Herbicides H1 and H4 showed identical effect on the height growth for both cultivars. Slowing in height growth for both cultivars was caused by the herbicide H2, and saplings remained with heights 99 cm (′I-214′) and 55 cm (′Vernirubens′).

Table 3. Influence of selective herbicides on the growth of cv. Vernirubens.

Variant / herbicide	Stem height, cm	Thickness of saplings in the basis of the stem, mm	Thickness of roots, mm	Av. number of roots 1-st grade
Control	146.02 ±5.47 c	18.25 ±0.51 e	4.08 ±0.19 de	23.78 ±0.72cd
H1	113.64 ±4.92 b	13.99 ±0.46 b	2.68 ±0.14 ab	16.89 ±2.37 b
H2	54.90 ±2.77 a	8.41 ±0.31 a	2.10 ±0.14 a	7.00 ±1.08 a
H3	178.67 ±5.59 e	20.00 ±0.49 e	3.57 ±0.16 c	63.67 ±0.78 e
H4	107.86 ±3.93 b	11.73 ±0.31 b	2.28 ±0.11 a	22.56 ±1.59 c

Note: The means and standard error within a column followed by the same letter were not significantly different.

View of representative saplings of the variants at cv. I-214 and cv. Vernirubens is presented in Fig. 1.

The criterion thickness in the stem basis showed that for both tested cultivars the herbicide H3 does not exhibit oppressing effect. The cultivar ′I-214′ forms thicker stems – from 20 mm (H3) to 22 mm (control). At cv. Vernirubens the stem diameter is within the frame from

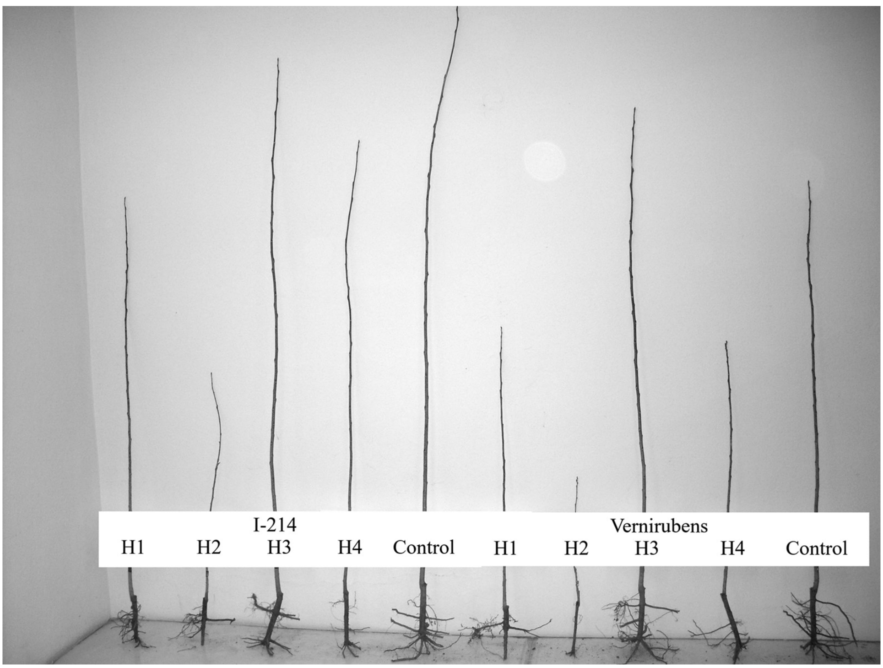

Fig. 1. Representative saplings of the variants at cv. I-214 and cv. Vernirubens.

18 mm (control) to 20 mm (H3).

The herbicide H2 oppressed most strongly the growth in thickness of the saplings in both cultivars, and the herbicide H3 oppresses least the growing of roots in thickness and showed identical effect on both cultivars.

The development of the roots system is related not only to the thickness but to the number of formed roots, as well. With highest number of roots at cv. I-214 were the saplings from variants H3 and control – average number of roots from 24 to 29.

At cv. Vernirubens most powerful root system was developed at variant H3 – average 64 roots, followed by variants H4 and control (23 and 24, respectively). Poorest root system was observed at the saplings treated with Select – average 7.

The results from the water content of tissues showed that from all tested variants increased value is available for variant H2, and the relative moisture is from 65 % to 68 %. For all other variants it is within the frame from 48 % to 54 % (Table 4).

Table 4. Influence of selective herbicides on the relative moisture of saplings.

Variant / herbicide	Relative moisture, %	
	'I-214'	'Vernirubens'
Control	50.50 ± .04 b	48.59 ±3.73 b
H1	48.20 ±0.88 b	53.11 ±0.98 b
H2	64.87 ±1.07 a	67.56 ±4.68 a
H3	53.33 ±1.42 b	53.58 ±1.56 b
H4	48.25 ±3.74 b	53.14 ±3.41 b

Note: The means and standard error within a column followed by the same letter were not significantly different.

The statistical analysis of results (Table 5) proved the influence of the two tested factors – cultivar and herbicide – according to growth indices. Only moisture of saplings was influenced by applied herbicide only.

Table 5. Statistical significance of factors influencing on the development of saplings.

Factors	Statistical significance of factors influencing on:											
	Thickness of saplings in the root cervix		Growth in stem height		Number of roots 1-st grade		Survival of saplings		Thickness of roots of 1-st grade		Moisture of saplings	
	F	Sg	F	Sg	F	Sg	F	Sg	F	Sg	F	Sg
Cultivar	85.23	0.000	229.20	0.000	15.13	0.000	6.16	0.013	6.16	0.013	1.47	0.228
Herbicide	108.50	0.000	130.20	0.000	82.12	0.000	50.86	0.000	50.86	0.000	4.42	0.003

Note: F – Fisher's exact test; Sg – significant level.

Conclusion

The obtained results outlined the following conclusions and recommendations:

Tested herbicides do not influence on the survival of saplings, except for negative effect on cv. Vernirubens, caused by the herbicide H2 (240 $g.l^{-1}$ Clethodim).

The cv. I-214 saplings show faster height growth compared to cv. Vernirubens for all variants.

Tested cultivars show specific reaction to used herbicides and best tolerance to the herbicide H3 (350 $g.l^{-1}$ Butachlor + 350 $g.l^{-1}$ Propanil). The specific reaction is expressed in the fact that cv. I-214 shows less tolerance to influence of herbicides than cv. Vernirubens.

Herbicides H1 (150 $g.l^{-1}$ Fluazifop-P-butyl) and H4 (240 $g.l^{-1}$ Oxyfluorfen) oppress less the saplings growth for both cultivars compared to the outlined depression effect of the herbicide H2 (240 g.l^{-1} Clethodim).

The effect of the tested herbicides showed that it cannot be counted only on the instructions of the producer for selectivity. The herbicide H4 (240 g.l^{-1} Oxyfluorfen), oppressing dicotyledonous plants, brought to comparatively good growth indices of the saplings. The herbicide H2 (240 g.l^{-1} Clethodim), oppressing monocotyledonous plants, caused slowing in the growth and phytotoxic reaction of the saplings.

In the course of production, the best for weed control is to be carried out through the herbicide H3 (350 g.l^{-1} Butachlor + 350 g.l^{-1} Propanil), which can be applied during all phoenophases in the development of saplings.

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