EXTENSIVE PRODUCTION OF MAPLE LARGE-SIZED PLANTING STOCK IN FOREST NURSERIES*

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Sycamore (*Acer pseudoplatanus*) is a woody plant with a broad spectrum of utilization: in forestry, landscape gardening, horticulture, and park plantings. An experimental cultivation of broadleaves large-sized saplings, carried out in 2006–2010, was evaluated within the frame of the project 'Optimization of woody plants production, important in landscape reconstruction and maintenance'. Mortality, height and width growth as well as growth dynamics within the growing season were measured as affected by application of slow-release fertilizer and response to climatic factors. The optimal fertilizer dose was affected by precipitation and varied between 50 and 100 kg of nitrogen per ha. The mortality of the saplings was within the range of 5–12% and was higher at the highest fertilizer dose and the control variant, without fertilization.

forest nursery; fertilizer; sycamore (*Acer pseudoplatanus*); saplings

INTRODUCTION

Production of large-sized planting material of horticultural trees has a long tradition not only in the Czech Republic, but in whole Central Europe (Dušek, 1980). Experiments with the cultivation and planting of large-sized woody plants, used in gardening and landscape projects – e.g. in alleys, have been documented since the sixteenth century. Currently, broadleaves large-sized planting stock, called 'poloodrostky' and 'odrostky', is used and defined by the norm ČSN 48 2115 (1998), according to the height and method of cultivation of the trees in forest nurseries (Jurásek et al., 2002). This type of plants has been applied in landscape and restoration plantings, as well as in forestry as ameliorative and stand stabilizing species and further to increase the recommended representation of broadleaves (Mauer, 1999). This type of plants has its clear position on the market provided the quality of such a planting material is guaranteed (Burda, Nárovcová, 2009). Common species, which could be used as large-sized saplings, are lime trees, oaks, beech, rowans, ashes, birches, and maples such as sycamore (*Acer pseudoplatanus*), which was selected as model plant for this study. The advantages of sycamore as a model plant consist in its quick height growth, measurable increments, noticeable response to fertilization, and low drought tolerance (Broadmeadow et al., 2005) as well as in measurable growth depressions in unfavourable environmental conditions (Morecroft et al., 2008). The growth and response of sycamore to environmental factors has been described in a number of articles (Millard, Proe, 1991; Mackie-Dawson et al., 1994; Weber-Blaschke et al., 2002; Černohous, Kacálek, 2008; Burda, Nárovcová, 2009). These studies, however, were focused mainly on mature forest stands (Broadmeadow et al., 2005), field observations or on the natural regeneration reaction of the tree to light. In contrast, the growth response of young sycamore plants to environmental factors is not well understood.

Our study explored extensive cultivation of sycamore large-sized planting material in a forest nursery without irrigation and the effect of fertilization and environmental factors (mainly precipitation and temperatures) on plant growth within the vegetation period. Entec Perfect (Agro Efekt s.r.o.), a slow-release fertilizer, was used as a part of the extensive treatment, decreasing the number of operations in the field (Balík, 1993; Dušek, 1997; Kupka, 2005).

* Supported by CIGA (Internal Grant Agency of the Czech University of Life Sciences Prague), Project No. 20101003

doi: 10.7160/sab.2012.430405

Table 1. Description of fertilization variants, slow-release combined fertilizer Entec Perfect (control variant free of fertilizer is not included)

Variant	Fertilizer (kg/ha)	Nitrogen (kg/ha)	Fertilizer (g/plant)
1	178	25	4
2	357	50	8
3	714	100	16
4	1071	150	24
5	1428	200	32
6	1758	250	64

MATERIAL AND METHODS

Sycamore plantation was established in the forest nursery Sepekov, close to Milevsko, in natural forest area (PLO) 16. The altitude of the site varies between 450 and 495 m a. s. l., the long-term, annual, mean air temperature is 7.9°C, the mean value for the vegetation period (May–October) is 15°C, and long-term annual rainfall makes 600 mm (daily climatic data were obtained from CHMI, Tábor station, 15 km distant from the experimental plot). Bedrock at the site is formed of syenite, soils are loamy, moderately heavy, and the forest nursery, where the experiment was established, is without irrigation.

Soil characteristics were determined according to the forest nurseries standard (K u p k a , 2005). Presented (May) characteristics are as listed: humus content 2%, pH (H_2O) 7.7, base content (S) 14.4 (mval/100 g), sorption capacity (T) 14.6 (mval/100 g), total nitrogen (Kjeldahl) 0.15%; accessible nutrients (in Mehlich III solution): phosphorus (P_2O_5) 387 mg/kg, K_2O 172 mg/kg, CaO 2567 mg/kg, MgO 197 mg/kg (difference within 0 and 6 variant) (K y l a r , 2010).

The results of measurements in four vegetation periods are presented. Each season, large-sized planting stock plants in their final year of cultivation were measured. In 2006, 2009, and 2010 the plants were measured first season, after the spring transplantation (cultivation formula Syc 1 – 1 + 1; which means Sycamore seedling once undercutted, once transplanted, 3 years old), as addition in 2007 the saplings were measured in their second year after transplantation (cultivation formula Syc 1 – 1 + 2). The reason for longer cultivation in this case was a relatively unfavourable vegetation period in 2006, after which the plants did not reach required parameters and their cultivation was prolonged at the same field to the next vegetation period. First results were published in diploma theses (K y l a r , 2010; N o h a , 2011).

The experiment was performed as a part of forest nursery running operations and as such it included standard application of herbicides and mechanical removing of weeds. Experiment started in the stage of mechanized transplantation of sycamore saplings with average root-collar width of 4 mm and height of 35–45 cm. Standard planting distance was 0.8 m between rows and 0.3 m within rows. As the planting distance was not strictly kept, and the differences of fertilization treatment too high, the experiment could not be arranged in random squares, which would have increased the influence of the adjacent treatment and decrease the transparency of the arrangement. The variants were therefore arranged in rows, with the high fertilization variants in the bottom part of the plot (very slight slope of 1.5%). Seven fertilization variants (and/or six in 2009 and 2010) were established and each was replicated 5 times, with 35 transplanted saplings in one replicate. Thus, 1050–1225 plants were measured in total per season (the highest fertilization variant 6 was omitted in 2009 and 2010).

The outplanting date depended on the possibility of mechanized operations in the field (and humidity of the soil) and varied therefore approximately in the range of the last week of April and the first weeks of May, within the seasons. Fertilizing and the first measurements were performed at the same date, the last week of May and the first week of June, usually 3–4 weeks after transplantation (to support rooting and exclude a negative effect of high fertilizer dose before rooting). The fertilization was performed by hand, specified amount (Table 1) was put to each plant, using the slow-release combined fertilizer Entec Perfect with the nutrient composition as follows: NPK 14–7–17+2 MgO plus nitrogen carbamide stabilizer DMPP (K y l a r , 2010). Overview of the fertilization variants is given in Table 1.

Height measurements were performed by measuring rod, monthly from fertilization time, since May till October (six times, approximately in 3–4 week periods, dates are indicated in Fig. 4) to record growth intensity in the course of the vegetation period. The measured parameters were: total plant height at the beginning H_0 (accuracy 0.5 cm) and during vegetation period $H_{1–5}$, and root-collar total width at the beginning D_0 and in the end D_5 (accuracy 0.5 mm). The increment was calculated from the measured values as a difference of the first and the current height (in given replication, variant, or finally four seasons) which explains negative increments in cases of damage by insects or drought. Mortality was calculated as the difference between the number of vital plants at the beginning and at the end of the vegetation season, in percentage.

Soil state assessment in the autumn of 2006 (U l b r i c h o v á , K y l a r , 2009) did not show significant differences between the variants, so it was not performed in the following years. Nutrient contents determined in foliar samples also did not differ significantly between the variants (K y l a r , 2010) and they were never in the deficiency range, not even in the Control.

Data of increment (height as well as root-collar width increment and mortality in particular treatments) were evaluated by One Way ANOVA followed

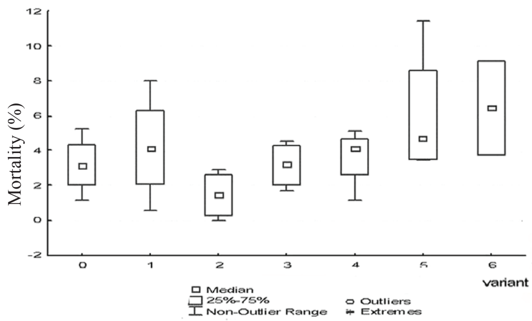

Fig. 1. Mean annual mortality of sycamore plants in different fertilization variants as an average from four seasons observation

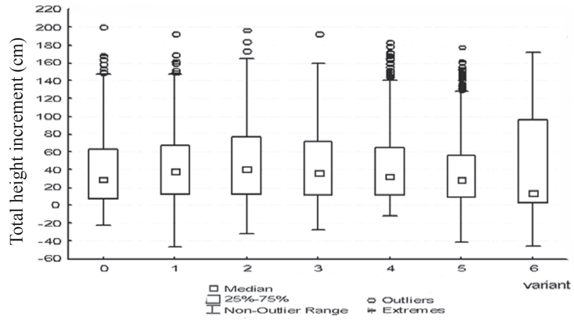

Fig. 2. Mean annual height increment of sycamore plants in different fertilization variants as an average from four seasons observation

by Tukey's interval test in S-PLUS programme, and these methods also confirmed homogeneity of the plant material in the range of different treatments and plots at the beginning of the experiment each year.

Effect of climatic factors was calculated for all four seasons together. In the case of precipitation, it was calculated by Pearson's correlation coefficient as an increment within the period of two field measurements and sum of precipitation in the same period, and for temperature, as an increment within the period between two field measurements and average temperature in the same period.

RESULTS AND DISCUSSION

Mortality

Total plant mortality varied between 2 and 20% in the individual replicates, 2–6% on average for the fertilized variants, showing a visible trend (Fig. 1) of increasing mortality with increasing fertilizer levels over 100–150 kg of nitrogen per ha or, in the opposite case, with a too low nutrient level in the control variant. Negative effect of too high nutrient levels in soil inducing soil acidification and increasing the effect of water deficiency, is well-known for field plants (B a l í k , 1993) and described also for woody plants (N a k o s , 1979). Sycamore is considered to be a woody plant with a higher demand for nutrients (M a c k i e - D a w s o n et al., 1994), but in the rich soil of the forest nursery, the high fertilization variants 5 and 6 (200 and 250 kg N/ha) decreased the increment and increased mortality of sycamore plants noticeably. Mortality of transplanted plants is also related to transplantation shock (M a t e r n a et al., 2002) and is much higher immediately after transplantation, than in the subsequent years.

Total height increment

The four years of evaluation of fertilizer effect on the mean value of height increment of large-sized sycamore planting stock places the optimal dose in the range of 350–700 kg of fertilizer per ha (accordingly 50–100 kg of N per ha) and 4 g of fertilizer per plant (Fig. 2) (or 0.12 g of N per plant). Similar pot experiment with sycamore saplings (W e b e r - B l a s c h k e et al., 2002) showed the height increments of 10–40 cm, and two years after transplantation even two times higher, with fertilization dose 3 g of nitrogen per plant (comparable with our variants 4–5).

The effect of fertilizer or soil substrate on the growth of sycamore was further described in the study of M a t e r n a et al. (2002). This study was focused on fertilizing with finely ground serpentinite substrate, the effect of which, however, consists mainly in adjusting calcium and magnesium levels, not that of nitrogen. The mean value of increment and total height can be also compared to the sycamore plantation in mountain condition (Č e r n o h o u s , K a c á l e k , 2008), but in that case, climatic conditions decreased the height increment to only 6–15 cm per year.

At the same time, Table 2 shows noticeably higher increment intensity two years after transplantation (in the 2007 season) and significant difference for the control variant and variants 2 and 4, with the mean value of height increment difference of about 20 cm, in the same season.

Table 2 and Fig. 2 also show very high increment variability between the years; fertilization intensity is apparently not the crucial factor affecting increment. An unfavourable drought period in the beginning of summer (as was the case in the 2006 season) decreased the mean value of height increment 3–4 times in comparison to the other seasons. Statistically significant differences were only between the control and variant 1. Measurements in the 2009 vegetation season confirmed the possibility to accomplish the large-sized planting stock (100–177 cm) cultivation in 4 years even in extensive cultivation provided climatic conditions are favourable. It can decrease the costs and enhance the production of large-sized planting material. Similar variability of total increment values were shown by B u r d a , N á r o v c o v á (2009). In their study, the total height of sycamore plants varied between 96 and 169 cm in the second year after transplantation depending on season, which implies a 60% difference attributable to the climatic factors of the given year.

Table 2: Mean values of height increment and Mean values of total height of sycamore plants (± standard deviation) in the first season after transplantation (2006, 2009, 2010) and the second season after transplantation (2007)

Var. fertilization	Syc 1-1+1 2006		Syc 1-1+1 2009		Syc 1-1+1 2010		Syc 1-1+2 2007	
	Increment (cm)	Height cm)	Increment (cm)	Height (cm)	Increment (cm)	Height (cm)	Increment (cm)	Height (cm)
0	8 ± 7 b	47 ± 9 b	23 ± 18 c	76 ± 23 c	52 ± 29 ab	178 ± 29 ab	87 ± 42 b	135 ± 41 b
1	10 ± 7	49 ± 10	44 ± 22 a	100 ± 25 a	45 ± 27 b	166 ± 27 c	92 ± 43	142 ± 43
2	11 ± 9 a	48 ± 10 a	37 ± 24 ab	93 ± 26 b	54 ± 31 a	184 ± 31 a	100 ± 37 a	149 ± 35 a
3	10 ± 9	47 ± 10	36 ± 23 b	90 ± 26 b	49 ± 38 ab	178 ± 38 ab	95 ± 35	142 ± 34
4	10 ± 9	48 ± 9	28 ± 20 b	83 ± 21 c	45 ± 23 b	178 ± 23 b	101 ± 43 a	149 ± 37 a
5	10 ± 9	46 ± 11	26 ± 20 bc	81 ± 24 c	41 ± 25 bc	164 ± 25 c	91 ± 42	138 ± 39
6	8 ± 8	46 ± 11					97 ± 48	143 ± 42

Note: letter indexes mark significant differences between values, by Tukey method, linear combinations, simultaneous 95% confidence limits

Root-collar width increment

Like for the mean value of height increment, the optimal dose for mean value of root-collar width increment (Fig. 3) was 100 kg of nitrogen per ha given in variant 2. In this variant, the mean value of width increment was about 7–8 mm, i.e. more than 100% of the initial value. In the 2006 season with unfavourable climatic conditions and low height increment, the mean value of root-collar increment reached 4.5–6 mm (i.e. almost 70–100% of the initial values). The (optimal) variant 2 significantly differed (Table 3) from the control as well as from the variants 5 and 6 with lower increments.

Černohous, Kacálek (2008) evaluated the effect of fertilization with finely ground amfibolite and limestone on sycamore large-sized plants with comparable root-collar width of 4–6 mm in a mountain site plantation. In their study, the root-collar increment was very small and our final width (8–9 mm) had not been reached until 5 years after transplantation, which was attributed to transplantation shock and harsh climatic conditions in the mountain stand.

Table 3: Mean root-collar increment of sycamore plants (± standard deviation) in the first season after transplantation (2006, 2009, 2010) and the second season after transplantation (2007)

Var. fertilization	Syc 1-1+1 2006	Syc 1-1+1 2009	Syc 1-1+1 2010	Syc 1-1+2 2007
	Root-collar (mm)	Root-collar (mm)	Root-collar (mm)	Root-collar (mm)
0	9 ± 2	12 ± 2 c	14 ± 2	17 ± 2 b
1	10 ± 2	15 ± 3 ab	14 ± 2	18 ± 2
2	10 ± 2	15± 3 a	15± 3 a	19 ± 3 a
3	10 ± 2	14 ± 3 ab	14 ± 3	18 ± 2
4	10 ± 2	14 ± 2 ab	14 ± 2	19 ± 2 a
5	9 ± 9	13 ± 3 bc	13 ± 2 b	17 ± 3
6	9 ± 2			17 ± 3

Note: letter indexes mark significant differences between values, by Tukey method, linear combinations, simultaneous 95% confidence limits.

Growth dynamics in the course of the vegetation period

Fig. 4 describes the height growth dynamics of transplanted saplings during the vegetation seasons (May to October). Typical dynamics shows postponed start of the growth due to transplantation shock, further intensively increasing height increment in June and its culmination in July and slowly decreasing growth in the second part of the vegetation period, usually till October, when the growth intensity visibly slows down, probably due to low temperatures (Burda, Nárovcová, 2009).

The exception from this trend was the 2006 season with exceptionally low precipitation in the end of June and in the first part of July. This resulted in an inadequately low increment (Kylar, 2010). Plants from this experiment, which did not achieve required parameters, were left on their place and were measured in the 2007 season, too. In the second year after transplantation, growth dynamics was strongly influenced

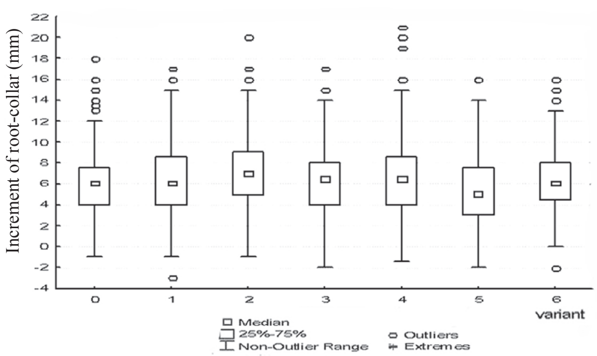

Fig. 3. Mean annual root-collar width increment of sycamore in different fertilization variants as an average from four seasons observation

Table 4: Annual average effect of evaluated climatic factors on the height and width increment of sycamore large-sized plants, by Person correlation coefficient, with 0.05 significance

Characteristics	Temperature	Precipitation	Temperature combined with precipitation	Higher importance
Increment	R^2	R^2	R^2	
Height increment 1	0.372	0.202	0.373	Temperature
Height increment 2	0.040	0.047	0.052	Precipitation
Height increment 3	0.138	0.270	0.376	Precipitation
Height increment 4	**0.736**	0.272	**0.841**	Temperature
Height increment 5	0.270	0.075	**0.784**	Temperature
Width increment D2	0.026	0.034	0.048	Precipitation
Width increment D2-D1	0.496	0.342	**0.676**	Temperature
Total increment	0.001	0.089	0.091	Precipitation

Note: Index of increment (1-5) means succession of field measurement marked cases - gives you more than 50% percent of variance in the dependent variable (growth of height and root-collar) that is predictable from the independent variables (temperature, precipitation).

by the established root system in the beginning of the season. Growth of plants started sooner than after transplantation, and increment was much higher already in May, intensive, and not so negatively influenced by inhibitory fertilizer levels (Fig. 4, variants 2 and 6 for the 2007 season).

Warm weather in the 2010 season delayed the end of the vegetation period and led to slow growth till the end of October (Fig. 4). Experiences with two-year old sycamore plants and fertilization were also described by Mackie-Dawson et al. (1994). In an experiment with nitrogen doses of 140 and 840 kg N per ha, the initial growth in the beginning of the vegetation season depended primarily on the nutrient status in the previous year, while fertilization influenced particularly the growth in the second half of the vegetation season. This study confirmed results published previously (Millard, Proe, 1991).

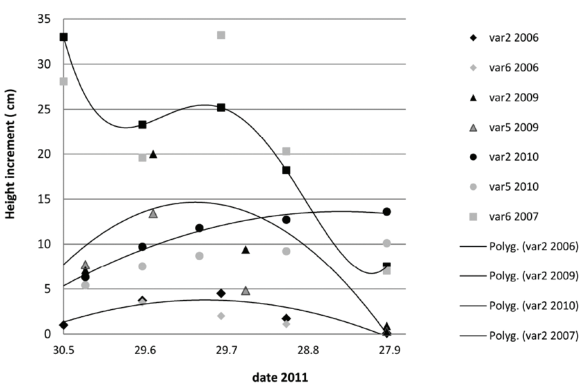

Fig. 4. Height growth dynamics of transplanted saplings of selected fertilization variants (optimum and maximum) during four vegetation seasons. The 2007 season onset deviation is a result of sooner growth start of not transplanted saplings

Effects of climatic factors

Precipitation and temperatures in the vegetation season were evaluated only during a relatively short period of four years, and considering their variability and interactions in the final effect on plants growth (Table 4), this period is too short to draw conclusions.

Correlation coefficient values between mean value of height increment and precipitation sum within measurement were mostly insignificant (Table 2), correlation between average temperature and mean value of increment was significant only in the 2006 season (R^2 = 0.558); together both climatic factors correlated with increment more, R^2 = 0.597 for the 2006 season, and R^2 = 0.360 for the 2009 season. The correlation was, however, low for the 2010 season, and for the plants two years after transplantation (the 2007 season), which had a better developed root system and were less influenced by low precipitation.

Sycamore is a relatively quickly growing woody plant, with low tolerance to drought or insufficient watering (Broadmeadow et al., 2005). Water deficiency can thus be the limiting factor in sycamore production. Climatic conditions in the Czech Republic do not ensure regular precipitation in the vegetation season and the probability of a summer drought period is approximately once in five years (Potop et al., 2008). This has to be taken into account in extensive cultivation in forest nurseries without irrigation.

CONCLUSION

The comparison of different doses of the Entec Perfect fertilizer resulted in the assessment of optimal dose of 50–100 kg of nitrogen per ha, (350–700 kg of fertilizer per ha, respectively) for the increment of sycamore saplings in the process of large-sized planting stock cultivation. Recommended fertilizer dose by the producer is 250–500 kg/ha, which is a slightly lower range, but our results confirm this recommendation. Visible symptoms of nutrient deficiency were not observed in any of the experimental variants, not even in the control without fertilization.

In a season with favourable climatic conditions, sycamore plants after transplantation (KL 1 – 1 + 1) reached an average height of 100 cm, i.e. their height increment was about 40% in the given year. Their root-collar width increment was 7–8 mm (150–200% of the initial value on average). In the second year after transplantation, the total height was up to 177 cm (which means height increment of about 30%).

The survival rate was the lowest in the control variant and treatments with the highest tested dose of fertilizers (250 kg N/ha), especially in combination with dry weather in the months following transplantation.

High variability in the data among vegetation seasons points to the predominant influence of climatic factors, especially at the season with drought in spring time (2006). The range of the mean value of height increment data from all four seasons amounted to tenths of centimetres. Statistical confirmation of the effects of specific climatic factors, however, would require a longer observation period. The effects of precipitation were also influenced by the quality of the root system and thus by the length of the cultivation period since transplantation.

In all cases, high variability of increment (height and width) within treatments and replications was observed, which could be the result of genetic variability of the plant material and probably also other, not measured characteristics like micro-scale differences in soil water accessibility and soil characteristics.

It seems, that on the rich and well cultivated soils of forest nurseries, the main production limiting factor is soil humidity. The success of cultivation thus depends on the precipitation and weather in the vegetation season in the case of extensive cultivation or on the possibilities of artificial irrigation in the given forest nursery.

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Received for publication on February 2, 2012
Accepted for publication on October 11, 2012

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Extenzivní pěstování poloodrostků javoru v lesních školkách

Scientia Agric. Bohem., *43*, 2012: 153–159.

Javor klen (*Acer pseudoplatanus*), je dřevinou s širokým spektrem využití: v lesnictví, ozeleňovacích i zahradnických výsadbách. V rámci sledování možností extenzivního pěstování listnatých poloodrostků, byl hodnocen poloprovozní experiment (v letech 2006-2010). Hodnocena byla mortalita, růstové charakteristiky a dynamika růstu v průběhu sezóny v souvislosti s optimální dávkou pomalu rozpustných hnojiv a reakcí na klimatické faktory – srážky a teploty v průběhu vegetace (pokus probíhal na nezavlažované ploše). Optimální dávka hnojiva byla ovlivněna množstvím dostupných srážek ve vegetační sezóně a pohybovala se mezi 50–100 kg N/ha. Mortalita rostlin se pohybovala mezi 5–12% a byla výrazně vyšší u kontroly a vyšších dávek hnojení.

lesní školky; hnojení; javor klen (*Acer pseudoplatanus*); sazenice

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