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INFLUENCE OF DIFFERENT CULTIVATION FACTORS ON BIOMETRIC FEATURES OF NORTH AMERICAN HACKBERRY (*Celtis occidentalis* L.)

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ABSTRACT

North American hackberry as a tree with resistance to Dutch elm diseases, pollutions and urban conditions is predisposed to becoming one of the common tree species for urban areas. Therefore, it is necessary to develop methods for nursery production of this species. The aim of this research was to determine the effect of fertilization and different methods of cultivation in rows with simultaneous use of geocomposite on the growth of North American hackberry in nursery production. Mechanical fallow in rows ha the most preferably influence, while living mulch with perennial ryegrass had rather negative impact on tested biometric features of North American hackberry. There was found a positive correlation between biometric features and foliar N content, as well as negative correlation between biometric features and soil salinity.

Key words: geocomposite, fertilization, mechanical fallow, perennial ryegrass, pine bark

INTRODUCTION

Polymeric soil conditioners as hydrogels were developed to improve the physical properties of soil. The most important feature is their ability to increase water-holding capacity, thereby increasing water use efficiency and reducing irrigation frequency. Addition of hydrogels also prevents excessive compaction of the soil [Jhurry 1997].

Superabsorbents indirectly affect the quality of cultivated plants by improving the physical properties of the soil. They increase the bioagent population thus boosting plant health by controlling soil pathogens population [Sabir et al. 2011]. Addition of hydrogels delays permanent wilting point of plants by a few days [Akhter et al. 2004], as well as increases seedling survival in periods of drought [Al-Humaid and Moftah 2007, Chirino et al. 2011]. Furthermore, they improve quality of the roots [Wang and Boogher 1987], positively affect biomass production and enhance other plant features such as height, stem diameter, leaf surface [Akhter et al. 2004, Mao et al. 2011, Orikiza et al. 2013], and overall decorative value of plants causing their abundant flowering [Boatright et al. 1997, Wróblewska et al. 2012].

Superabsorbents in crop production have been in use since the 80's of the last century. Since then many studies with hydrogel use have been carried out, which indicates positive effects on physical, chemical and biological properties of soil and plant biometric features [El-Hardy and Abo-Sedera 2006, Sarvaš et al. 2007, Yazdani et al. 2007, Dereń et al. 2010]. The impact of hydrogel use along with fertilization and a combination of hydrogel with different cultivation

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methods in rows has been tested but simultaneous operation of all mentioned factors never been studied.

Producing good quality nursery stock is the primary goal of ornamental nursery. Good quality trees are characterized by suitable parameters such as the height and also magnitude of the corona resulting from the shoots number and their length. Geocomposite used in this research represents an innovative technology that incorporates an agrotextile tape filled with superabsorbent. This allows for its convenient placement directly in the root zone of plants and offers the possibility of removal at the end of finished production cycle. Plant roots can easily outgrow agrotextile, which allows the plant to use water and ions retained in the hydrogel matrix.

North American hackberry and elm trees belongs to the same family *Ulmaceae*. Both species are quite common, not only in North America where they are from, but also in Europe. However, in contrast to elm trees, North American hackberry is a species with natural resistance to Dutch elm diseases. This disease is caused by fungus genus *Ophiostoma*. There are three identified species: *Ophiostoma ulmi,* the highly virulent *O. novo-ulmi,* which almost totally replaced *O. novo-ulmi* and exists in two subspecies (Eurasian form EAN – *O. novo-ulmi* ssp. *novo-ulmi* and American form NAN – *O. novo-ulmi* ssp. *americana*) and *O. himal-ulmi* identified in Himalayas but its presence has still not been reported in Europe and North America [Brasier and Mehrotra 1995, Brasier 2000, Brasier and Kirk 2001]. This disease resistance together with pollutions and urban conditions resistance makes this tree predisposed to becoming one of the common species for urban areas. Therefore, it is necessary to develop methods for nursery production of this species. The aim of this research was to determine the effect of fertilization and different methods of cultivation in rows on the selected biometric features of North American hackberry trees with geocomposite implemented to the root zone.

MATERIAL AND METHODS

The field research was carried out in April 2011 and lasted three years in the Research-Development Station of Vegetables and Ornamental Plants in Psary near Wrocław. Four-years old seedlings of North American hackberry (*Celtis occidentalis* L.) grown in C2 type pots were used in this experiment. Each combination consisted of 3 replications of 5 plants in each replication. Trees were planted into a class III degraded soil, build of light clays. The organic matter content was 1.8%, pH (determined in distilled water at a volume ratio of 2:1water to soil) was 8.26 and salinity was 155 µS cm^{-1}. At the beginning of research nutrients content (mg dm^{-3}) in soil were: $N\text{-}NO_3$ – 65, P – 34, K – 125, Mg – 138 and Ca – 4800. The furrows of 30 cm depth were plowed along the scheduled rows within 2.6 m each. The geocomposite, previously soaked in tap water for 24 hours, was placed in each furrow. It had a form of a 8-cm-wide tape made of a white geotextile filled with polyacrylic acid potassium salt with a determined adsorbing capacity of 60 cm^{-3} of distilled water per 1 g of substance. The root system of plants was placed directly on the geocomposite within 1 m of another tree, covered with soil and watered thoroughly. Main shoot was tied to the cane and the side shoots were cut in the spring above the third bud annually and selected combinations were fertilized. Mechanical weeding in the inter-rows and in selected combinations was made during the growing season.

Fertilization with a multi-nutrient fertilizer YaraMila Complex composed of N – 12% (including $N\text{-}NO_3$ – 5%, $N\text{-}NH_4$ – 7%), $P\text{-}P_2O_5$ – 11%, $K\text{-}K_2O$ – 18%, Mg-MgO – 2.7%, S – 8%, B – 0.015%, Fe – 0.2%, Mn – 0.02% and Zn – 0.02% at a dose of 6 g in the first year, 15 g in the second and 30 g in the third per plant was the first factor considered in the experiment (presence or absence), while the method of cultivation in rows (pine bark mulch, living mulch with perennial ryegrass and mechanical fallow) was considered the second one. The use of geocomposite was a constant factor not taken into account in the statistical analysis.

In the experiment six combinations with geocomposite were used:

– pine bark mulching with fertilizer,
– pine bark mulching without fertilizer,
– perennial ryegrass living mulch with fertilizer,
– perennial ryegrass living mulch without fertilizer,
– mechanical fallow with fertilizer,

– mechanical fallow without fertilizer.

After the end of the growing season in late October and early November in years 2011–2013 measurements of tree height, crown diameter, trunk girth at a height 1.3 m, the number of annual shoots, and their length were made. The parameters of weather conditions (temperature and precipitation) were also monitored.

The data was subjected to the analysis of variance (ANOVA). The *F*-test was used to identify the treatments main effects and interactions followed by Tukeys multiple range test at the 0.05 probability level. Simple correlation coefficient between biometric features of North American hackberry and nitrogen content in leaves and soil salinity was calculated using Statistica v.12.5. The analysis was performed separately for each year of the study (n = 18). Differences was proven with the risk of error less/equal to 5%.

RESULTS

Weather conditions

Weather conditions in individual years were varied and had a significant impact on the research and on biometric features of North American hackberry. For the evaluation of thermal and pluviometric conditions, apart from the average monthly temperatures and total precipitation (tab. 1) a hydrothermal Sielianinow's coefficient was calculated (fig. 1), which shows the duration and the intensity of drought and mild drought affecting the growth and development of plants [Radomski 1987].

In the first year of research (2011) unfavorable weather conditions for the development of North American hackberry were recorded. Winter was characterized by higher air temperature in comparison with long-term average, the amount of precipitation was significantly lower than in 1991–2000. Moreover, water shortages have also been reported at the beginning of vegetation. In April and May 2011 mild drought occurred and in June – the drought (precipitation was lower by 41.1 mm than in long-term period with simultaneous higher mean air temperature by 2.1°C). Such the weather conditions affected limited growth and development of trees. Proper soil moisture was observed only in July, in which the amount of water was above 150 mm. By the end of growing season the precipitation was much lower than in 1991–2000 with higher air temperature at the same time.

Within the second year of study (2012) winter was characterized by a generally favorable weather course. Significant water shortage was recorded in April and in May, in which mild drought and drought were noticed. Precipitation was lower than in 1991–2000 respectively by 51 and 63% with simultaneously higher air temperature, respectively by 1.6 and 2.1°C. To the end of the growing season the weather conditions were similar to those found in long-term period with the exception of very warm August in which a very mild drought was recorded, despite the rainfalls similar to the average.

The most favorable for the growth of North American hackberry was the last year of studies (2013). From January to March the average air temperature was lower than in long-term period, while precipitation generally exceeding average from 1991–2000 and secured plants from mild drought, which took place in April. In May and June the average amount of precipitation and air temperature were slightly higher than in long-term average, what resulted in better growth and development of hackberry. Unfortunately, in July and August the drought occurred, the amount of rainfalls made up respectively 30 and 73% of average precipitation in the years 1991–2000 and the air temperature was by 1.1 and 2.3°C higher than long-term average. Significant water shortage was supplemented with rainfalls in September, in which the amount of precipitation was by 94% higher than the average of the years 1991–2000.

Biometric features

Based on the results obtained in this study, non-fertilized plants were definitely higher in the first year of cultivation, while fertilized trees took over in the next two years. In each year of research plants cultivated with perennial ryegrass were the lowest. Trees maintained in mechanical fallow were tallest in all three years of cultivation. With the factors cooperation exact effect on the height of trees cannot be determined. In the third year, which had the most favorable weather course, trees height increased above 1 m compared to the previous year (tab. 2).

Clearly, fertilization had a significant effect on crown diameter only in the second year of cultivation, where trees fertilized had larger crown diameter than non-fertilized. The best method of cultivation in all three years was mulching with pine bark, in the third year also with maintaining in mechanical fallow. In all three years the most unfavorable cultivation method was the method with living mulch with perennial ryegrass. Trees cultivated according to this method always had the lowest values of crown diameter. Taking into account factors interaction, the largest crown diameter in second and third year had trees mulched with pine bark with simultaneous fertiliza-

Table 1. Monthly mean air temperatures and precipitation total during North American hackberry cultivation

	Year	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean temperature (°C)	2011	0.7	1.1	5.6	13.2	14.9	19.1	18.2	19.4	15.9	9.7	4.8	4.3
	2012	1.2	4.2	7.4	10.7	15.9	17.2	20.1	19.7	14.8	5.6	0.0	0.0
	2013	-1.0	0.1	-0.8	8.9	14.3	17.1	20.0	21.0	13.8	11.6	5.8	0.7
	Long-term average 1991–2000	0.1	0.9	4.0	9.1	13.8	17.0	18.9	18.7	14.0	9.0	3.4	0.3
Precipitation total (mm)	2011	31.6	10.6	24.0	24.0	41.4	21.9	153.2	22.7	21.8	29.0	0.0	32.5
	2012	67.8	36.6	6.9	15.6	20.5	77.1	70.8	48.4	45.0	31.4	0.0	0.0
	2013	49.0	27.3	29.0	22.1	57.5	86.2	28.3	37.0	93.0	5.4	23.1	10.6
	Long-term average 1991–2000	23.0	25.0	42.0	32.0	55.0	63.0	93.0	51.0	48.0	30.0	30.0	30.0

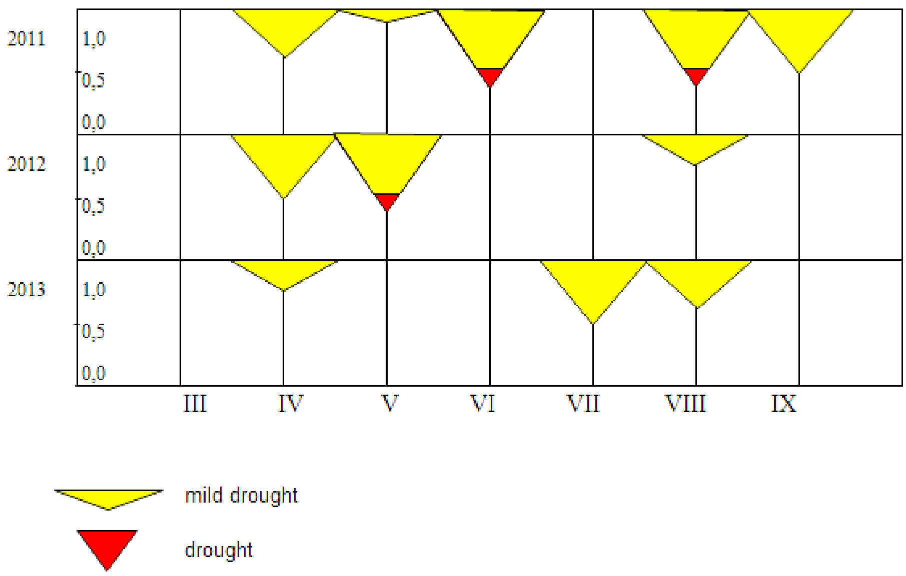

Fig. 1. Periods of mild drought and drought (Sielianinow's coefficient) during vegetation of North American hackberry

tion and the smallest were plants growing with perennial ryegrass as living mulch without use of fertilizer. Crown diameter in 2013 increased about 60 cm in comparison to 2012, which was less favorable, and only half of that increase was observed between 2011, which had the less favorable weather course, and 2012 (tab. 3).

First factor, which was fertilization, had a significant effect on trunk girth in the second and third year of cultivation, where the fertilized trees had largest trunk girth than unfertilized. In all three years the largest trunk girths were observed in trees maintained in mechanical fallow, while the smallest had trees cultivated with living mulch with perennial ryegrass. Taking into account factors interaction in the second and third year there is a tendency to obtain the best results while maintaining in mechanical fallow without fertilizer use and the lowest values were found in living mulch with perennial ryegrass without fertilizer use (tab. 4).

Table 2. The influence of different methods of cultivation on height of North American hackberry in three years of cultivation

	With geocomposite use												
	fertilization (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)
		PBM	PR	MF		PBM	PR	MF		PBM	PR	MF	
		2011				2012				2013			
Height (m)	with	2.19	1.79	2.25	2.08	2.37	2.03	2.85	2.42	3.90	3.53	4.09	3.84
	without	2.18	1.99	2.23	2.13	2.22	2.11	2.48	2.27	3.57	3.09	4.19	3.62
	$\bar{x}$ (B)	2.19	1.89	2.24		2.30	2.07	2.67		3.74	3.31	4.14	
		LSD (A) – 0.04				LSD (A) – 0.05				LSD (A) – 0.05			
		LSD (B) – 0.05				LSD (B) – 0.06				LSD (B) – 0.06			
		LSD (A × B) – 0.07				LSD (A × B) – 0.08				LSD (A × B) – 0.08			

PBM – pine bark mulch, PR – living mulch with perennial ryegrass, MF – mechanical fallow
LSD – least significant difference, n.s. – not significant

Table 3. The influence of different methods of cultivation on crown diameter of North American hackberry in three years of cultivation

	With geocomposite use												
	fertilization (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)
		PBM	PR	MF		PBM	PR	MF		PBM	PR	MF	
		2011				2012				2013			
Crown diameter (m)	with	2.10	1.37	1.70	1.72	2.47	1.53	2.10	2.03	3.00	2.10	2.80	2.63
	without	2.17	1.30	1.87	1.78	2.20	1.50	1.83	1.84	2.87	1.83	2.83	2.51
	$\bar{x}$ (B)	2.14	1.34	1.79		2.34	1.52	1.97		2.94	1.97	2.82	
		LSD (A) – n.s.				LSD (A) – 0.18				LSD (A) – n.s.			
		LSD (B) – 0.21				LSD (B) – 0.21				LSD (B) – 0.18			
		LSD (A × B) – n.s.				LSD (A × B) – 0.15				LSD (A × B) – 0.16			

PBM – pine bark mulch, PR – living mulch with perennial ryegrass, MF – mechanical fallow
LSD – least significant difference, n.s. – not significant

Table 4. The influence of different methods of cultivation on trunk girth of North American hackberry in three years of cultivation

		With geocomposite use											
	fertilization (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)
		PBM	PR	MF		PBM	PR	MF		PBM	PR	MF	
		2011				2012				2013			
Trunk girth (cm)	with	8.6	3.7	11.3	7.9	11.9	6.7	14.3	11.0	15.7	11.1	17.2	14.7
	without	8.3	4.7	10.7	7.9	10.5	5.7	15.6	10.6	13.9	9.1	18.5	13.8
	$\bar{x}$ (B)	8.5	4.2	11.0		11.2	6.2	15.0		14.8	10.1	17.9	
		LSD (A) – n.s. LSD (B) – 0.6 LSD (A × B) – 0.8				LSD (A) – 0.3 LSD (B) – 0.6 LSD (A × B) – 0.9				LSD (A) – 0.4 LSD (B) – 0.5 LSD (A × B) – 0.7			

PBM – pine bark mulch, PR – living mulch with perennial ryegrass, MF – mechanical fallow
LSD – least significant difference, n.s. – not significant

Table 5. The influence of different methods of cultivation on number of side shoots of North American hackberry in three years of cultivation

		With geocomposite use											
	fertilization (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)
		PBM	PR	MF		PBM	PR	MF		PBM	PR	MF	
		2011				2012				2013			
Number of side shoots	with	18.1	11.6	19.7	16.5	24.1	17.8	25.2	22.4	42.4	36.2	36.1	38.3
	without	16.5	14.5	18.2	16.4	17.7	16.1	18.0	17.3	35.2	25.5	49.1	36.6
	$\bar{x}$ (B)	17.3	13.1	19.0		20.9	17.0	21.6		38.8	30.9	42.6	
		LSD (A) – n.s. LSD (B) – 1.2 LSD (A × B) – 1.6				LSD (A) – 0.9 LSD (B) – 1.1 LSD (A × B) – 1.5				LSD (A) – 1.1 LSD (B) – 3.3 LSD (A × B) – 4.7			

PBM – pine bark mulch, PR – living mulch with perennial ryegrass, MF – mechanical fallow
LSD – least significant difference, n.s. – not significant

Table 6. The influence of different methods of cultivation on length of side shoots of North American hackberry in three years of cultivation

		With geocomposite use											
	fertilization (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)	method of cultivation (B)			$\bar{x}$ (A)
		PBM	PR	MF		PBM	PR	MF		PBM	PR	MF	
		2011				2012				2013			
Length of side shoots (cm)	with	30.3	19.3	19.7	23.1	69.8	44.7	52.7	55.7	116.7	94.4	117.3	109.5
	without	33.1	17.0	31.3	27.1	44.6	19.0	50.9	38.2	113.6	77.5	123.9	105.0
	$\bar{x}$ (B)	31.7	18.2	25.5		57.2	31.9	51.8		115.2	86.0	120.6	
		LSD (A) – 1.1 LSD (B) – 1.3 LSD (A × B) – 1.9				LSD (A) – 1.3 LSD (B) – 1.6 LSD (A × B) – 2.3				LSD (A) – 3.9 LSD (B) – 4.7 LSD (A × B) – 6.7			

PBM – pine bark mulch, PR – living mulch with perennial ryegrass, MF – mechanical fallow
LSD – least significant difference, n.s. – not significant

Fertilization had also a significant effect on numbers of side shoots during the second year and the third year of cultivation, where more side shoots were formed in fertilized trees. Taking into account the method of cultivation during the whole experiment the least number of side shoots was determined in plants cultivated with perennial ryegrass as living mulch and the largest number of side shoots was present in trees maintained in mechanical fallow. Factors interaction influenced the least number of side shoots in the second and the third year was living mulch with perennial ryegrass without use of fertilizer. There is no clear tendency with obtaining the largest number of side shoots during factors interaction. Number of side shoots between 2012 and 2013 with the most favorable weather course increased by approximately 20 shoots, while between the less favorable 2011 and temperate 2012 only by 1–6 shoots (tab. 5).

The results showed, that fertilized trees had longer side shoots in the second and the third year of cultivation. In all three years the most unfavorable cultivation method was living mulch with perennial ryegrass. Trees cultivated according to this method always had the shortest side shoots. The longest side shoots in the first two years had plants mulched with pine bark but in the third when using a mechanical fallow. In all three years of study the factors interaction influenced the shortest side shoots in trees growing with perennial ryegrass as living mulch without use of fertilizer. There is no clear tendency with obtaining the longest side shoots during factors interaction. The increase in shoot length between 2011 and 2012 was at the level of 25 cm, while between 2012 and 2013, which had the most favorable weather course, has doubled (tab. 6).

In all the years of research a significant positive correlation between selected biometric features and total nitrogen content in leaves of North American hackberry was found. In 2011 it was observed that the increase of nitrogen content by 1% favored the vegetative development of tested tree – hackberry was higher by 51 cm, its trunk circumference increased by 8.7 cm and the number of side shoots grew by 7.7. The same change direction, but with a slightly greater features independence was also proven in 2012 and 2013. Trees height increased, respectively, by 87 and 92 cm, trunk girth by 11.3 and 7.8 cm and the number of side shoots 5.9 and 10.4. (tab. 7).

The analysis of linear correlation also showed a significant association between biometric features and soil salinity. The increase in salinity primarily resulted in shortening the side shoots (correlation coefficient *r* was respectively -0.491 in 2011, -0.564 in 2012 and -0.900 in 2013). Soil salinity was related

Table 7. Correlation coefficients and simple regression equations between biometric features of North American hackberry and foliar N content and soil salinity in years 2011–2013

Treatment	Year	Plant height (m)	Crown diameter (m)	Trunk girth (cm)	Number of side shoots	Length of side shoots (cm)
Foliar N content (% of fresh weight)	2011	0.536* y = 0.51x + 1.31	-0.018	0.633* y = 8.69x – 5.70	0.557* y = 7.69x + 4.42	-0.192
	2012	0.896* y = 0.87x + 0.83	0.265	0.893* y = 11.3x – 8.77	0.472* y = 5.95x + 9.52	0.420
	2013	0.813* y = 0.92x + 2.11	0.468	0.782* y = 7.76x + 0.59	0.485* y = 10.4x + 19.1	0.644* y = 30.5x + 53.5
Soil salinity ($\mu S \cdot cm^{-1}$)	2011	0.086	-0.493* y = -0.0076x + 2.7	0.005	0.172	-0.491* y = -0.15x +43.3
	2012	-0.502* y = -0.005x +3.32	-0.480* y = -0.006x + 3.09	-0.781* y = -0.108x + 30.5	-0.279	-0.564* y = -0.32x + 105
	2013	-0.809* y = -0.015x +6.49	-0.773* y = -0.017x + 5.57	-0.734* y = -0.122x + 36.3	-0.755	-0.900* y = -0.71x + 236

* Significant correlation (α = 0.05)

to the crown diameter to a lesser extent (r = -0.493 in 2011, -0.480 in 2012 and -0.773 in 2013). The concentration of soluble salts in the soil also contributed to a reduction in plant height and trunk girth – it was proven only in the last two years of study (tab. 7).

DISCUSSION

In all three years of cultivation the largest trunk girths of North American hackberry were observed in trees maintained in mechanical fallow. These results corroborate previous studies of Licznar-Małańczuk [2012], which found the best radial growth of trees, determined by trunk sectional area, in herbicide fallow and with agrotextile mulching. First two years of North American hackberry cultivation showed that trunk girth was not affected by the use of fertilizer and our results are similar to those obtained by Raese et al. [2007] where trunk girth was not affected by the different N rates of fertilizers. The significant effect of fertilization on this biometric feature in North American hackberry was observed in the second and third year of cultivation and fertilized plants had larger trunk girth than unfertilized. Moreover, in the second and third year, trees cultivated with fertilization were higher and had longer shoots in comparison to unfertilized plants. Lower values of this features obtained in the first year might be associated with too much fertilizer and/or retention of water and ions in the hydrogel matrix and thus the competition for resources between the hydrogel contained in the geocomposite and plants roots. In some cases most of the water retained in hydrogel is bound so strongly that plants cannot use it to gain but only to sustain vital functions [Jaroszuk-Sierocińska and Słowińska-Jurkiewicz 2008]. Furthermore, nutrition deficiencies resulting from the retention of the nutrients in the hydrogel may appear. Rowe et al. [2005] showed that in some cases acrylic polymers may act as ion exchange resins, which result in deficiencies of divalent ions, such as calcium, magnesium or iron. The cause is a strong binding between them and the carboxyl groups of the hydrogel thereby preventing those ions from uptake by plant roots. Such strong competition for nutrients can influence directly on plants growth.

The results of three years of research show that in the case of North American hackberry cultivation, the geocomposite interaction with fertilization in the first year had rather negative effect on the biometric features, especially on the measurement of the shoot length and height. However, this combination did not cause necrosis of seedlings contrary to Arevalo's [2009] results in which found a negative effect of hydrogels used simultaneously with fertilization on the survival of Canary Island pine seedlings.

The use of living mulches is a popular method to maintain the proper parameters of soil and reduce weed infestation and thus to obtain good quality crops with reduced labor input. In North American hackberry use of living mulch with perennial ryegrass had negative effect on all biometric features during all three years of study and the best biometric features were obtained by North American hackberry grown in mechanical fallow. As reported by Derr [2001], limited growth rates of trees, especially young ones, could be related to significant weed infestations in orchards. A similar effect is caused by the presence of living mulches that increase competition for water, nutrients and space within the root system [Hoagland et al. 2008]. Shoot length and total annual growth of examined trees were consistent with the data reported earlier by Licznar-Małańczuk [2012]. In both cases the least number of the shortest length of shoots were produced by trees growing with living mulches.

In cultivation of North American hackberry which the highest number of shoots in all years of study obtained while maintaining in mechanical fallow. This does not coincide with the result obtained by Matta et al. [1981], who noted that in the case of white fir trees mulching with black foil, colorless foil, straw, sawdust, black foil with straw, black foil with sawdust and without mulching produced statistically the greatest number of shoots. The highest trees of North American hackberry were observed in all years of cultivation in mechanical fallow, while the lowest were always trees growing with perennial ryegrass. On the other hand, research of Matta et al. [1981] showed no effect of mulching on the growth of Austrian pine and Scotch pine.

In North American hackberry fertilized plants were higher and had longer shoots, whereas the results obtained by Wrona [2011] show that nitrogen fertilization had no significant effect on tree growth in comparison to unfertilized ones. This reaction of North American hackberry may be due to a very strong retention of cations and anions supplied along with fertilizers in pine bark mulch, the uptake by perennial ryegrass roots and/or storage in its tissues, as well as retention in the hydrogel matrix contained in the geocomposite. Mulch, geocomposite and ryegrass compete in fact with North American hackberry for nutrients. Moreover, in North American hackberry cultivation the use of multi-nutrient fertilizer did not affect the superior growth of trees in the first year but increased tested features in the next two years of research. Similar are the results obtained by Treder [2006] which shows that at the beginning of the study the strongest growth was observed in trees fertilized with nitrogen fertilizer but finally the highest were trees fertilized with multi-nutrient fertilizer.

In all three years of studies a positive correlation between plant height and the content of N in leaves was found. Liang et al. [2014] in the research into larch also showed that tendency – trees with higher N content in needles were higher. In our research a positive correlations between trunk girth and foliar N content and between the number of side shoots and foliar N content were also found. It might be affected by better N nourishment and thus stronger vegetative growth. In all three years of studies a negative correlation between crown diameter and soil salinity was noticed. The research of Benyon et al. [1999] also shows the reduction of crown volume with increasing salinity in *Eucalyptus occidentalis* and *E. camaldulensis*. Moreover, in North American hackberry the crown diameter may be also affected by shoot length and in all three years of studies a negative correlation between soil salinity and shoot length was also found. Similar results were obtained by Bader et al. [2015], where shoot elongation of olive tree 'Meski' and 'Ascolana' declined sharply as salinity increased. Also the results of Incesu et al. [2014] confirm, that by increasing salinity level the shoot length of two persimmon rootstock *Diospyros kaki* and *D. virginiana* significantly decreased. In the second and the third year of our studies a negative correlations between tree height and soil salinity, as well as between trunk girth and soil salinity were observed. In research conducted by Naeini et al. [2006] in pomegranate 'Malas Torsh' and 'Alah Torsh' the reduction of stem length with increasing salinity was also noted, while in *Tamarix chinensis* [Cui et al. 2010] two negative correlations were found: between plant height and salinity as well as between stem diameter and salinity.

CONCLUSIONS

1. Mechanical fallow in rows had the most preferably influence on growth parameters of North American hackberry.
2. Conversely, living mulch with perennial ryegrass had rather a negative impact on cultivation of the studied tree species.
3. There was found a positive correlation between biometric features and foliar N content, as well as negative correlation between biometric features and soil salinity.

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