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SOIL PROPERTIES AND PRODUCTIVITY PLANTATIONS OF TILIA CORDATA IN VARIOUS FOREST CONDITIONS

In Belarus there are 341.8 ha of plantations with linden artificially-descent and 3,746.2 ha of natural origin. Lime stands are distributed unevenly through the territory of the Republic and by class of age. The largest area with Linden widespread in the subzone of broadleaved and spruce forests (3,229.4 ha). There is a predominance of middle-aged stands (the average age is proportional to the square – 45 years). Lime stands grow mainly in oxalis (72.5% of the total area) and snidely (22.4%) forest types. To study the productivity of plantations and soil properties were mortgaged plots in stands of various composition and origin in different types of forest growing conditions and forest types (linden oxalis, blueberry and fern). For each horizon of the soil granulometric composition, content of humus, mobile forms of phosphorus, exchange potassium, iron rolling, the exchange cations of calcium and magnesium, acidity, calculated cation exchange capacity and saturation of soil bases. As a result of the research showed that the lime stands grow on sandy, sandy loam, sandy loam, underlain by clay and loamy soils. The higher average gains on a stock are pure and mixed lime stands of artificial origin, planted on sandy loam, underlain by loam and loamy soils in various forest types.

Key words: productivity, planting, soil fertility, humus, forest type.

Introduction. Tilia is a valuable species. It is actively used in forest-cultural production, at creation of field-protecting belts, in towns landscaping. Lime tree is one of few tree species which find application in various production spheres. They widely use wood which is noted for its lightness, viscosity and softness. Bark is used for production of bast and bast-fiber products. Bark, flowers and inflorescences, leaves, flower buds, fruits are stored up as crude drugs. Flowers contain essential oils (0.05%), possess properties of volatile production, lime blossom is used in perfumery. Oil is obtained from lime seeds which is highly appreciated in medicine and confectionery business. Leaves and young shoots of lime are an excellent forage for domestic animals. One of the main advantages of lime is its property to produce honey. It is unrivalled as a honey plant in the domestic flora, lime flowers are a source of valuable and fragrant honey [1].

Lime trees plantations of natural and artificial origin extend non-uniformly on the territory of Belarus. The total area of plantations is about 4,088 hectares with age up to 170 years with the general store of stem wood of 281.2 thousand m^3. Forest cultures including lime trees grow on the area of 341.8 hectares. From the point of view of geobotanical subareas there is decrease in lime trees areas from north to south (in the subarea of broadleaf-spruce forests there are 3,229.4 hectares of plantations, of these forest cultures occupy the area of 189.3 hectares, in the subarea of spruce-hornbeam oak-woods – 679.9 hectares of plantations, of these forest cultures – 74.7 hectares, in the subarea of hornbeam oak-woods – 178.3 hectares of plantations, of these forest cultures – 77.8 hectares). The greatest area fields with prevalence of lime trees are in Goretsky (1,291.1 hectares), Klimovichsky (352.7 hectares), Lioznensky (134.8 hectares), Mogiliov (161.6 hectares), Orshansky experimental (269 hectares), Novogrudsky (147.7 hectares), Volozhinsky experimental (156.4 hectares), Osipovichsky experimental (118.1 hectares) forestries, and that adds up to about 64% of area of all such plantations. The weighted average age of all plantations (proportional to the area) is 45 years. Degree of closeness of plantations is mainly 0.6–0.8, however there are fields with degree of closeness 0.3.

Lime tree is demanding to the soil fertility. Optimum are fresh and moderately wet, rich with wood humus, loose and well drained sabulous and light loam soils [2]. Lime trees can stand bog formation, but can tolerate an increased soil acidity. Thanks to presence of calcium in leaves, the tree waste reduces the soil acidity while decomposing and enriches it with humus, thereby promoting fertility enriching of sour soils more actively than oak, larch and other main forest species. Lime tree plantations are mainly presented by oxalis (72.5% of the total area), ashweed (22.4%) and bilberry (3.1%) forest types. Fern and nettle forest types are less often.

Main part. The researches objective is to study the success of growth of lime tree forest cultures in plantations of natural and artificial origin, of different species composition, age, soil conditions.

To study the lime tree plantations efficiency and soil properties six sample plots were chosen in middle-aged and almost ripe pure and mixed plantations of lime trees of natural and artificial origin (Table 1). Taxation indexes were measured on the sample plots, soil cuts were put and soil samples were taken from each genetic horizon. Soil grading (according to Sabanin method) and agrochemical

properties of soils were determined in laboratory conditions: humus content according to the method of Tiurin, pH in KCl on rn-meter HANNA HI 931400, hydrolytic acidity according to the method of Kappen, calcium and magnesium content with the help of trilon B, content of metabolic potassium on a flame photometer, content of mobile phosphorus on PhEC, content of mobile iron with the help of the method of Kirsanov. Absorption capacity and saturation degree of soils with foundations were calculated according to the data of hydrolytic acidity and content of calcium and magnesium.

Sample plot 2 (SP 2) is chosen in the mixed plantation of natural origin, the rest of sample plots are chosen in forest cultures of various species composition in oxalis and bilberry lime-tree forests. The age of analyzed plantations is 35–65 years. Degree of closeness varies from 0.51 to 0.73. The stem wood stock depending on age is from 80 m^3 at the age of 35 to 220 m^3 at the age of 55–65. Plantations mainly grow according to the 1st quality class with the mean increment from 2.9 (bull ray lime-tree forest) to 4.3 m^3/hectares a year (oxalis lime-tree forest).

Table 1

Taxation characteristic of forest stands

Sample number	TOFC/ forest type	Composition	Age, years	Height, m	Diameter, cm	Quality of soil	Degree of close-ness	Stock, m^3/hectare	Mean increment, m^3/hectare a year
1	C_2/Lp. ox.	10Lp	40	16.9	25.1	I	0.73	170	4.3
2	B_2/ Lp. br.	5Lp2Mp1Wil2Ash	45	19.2	24.0	I	0.52	130	2.9
3	B_3/ Lp. bl.	6Lp2P1Pn1B	35	14.3	14.2	I	0.51	80	2.3
4	C_3/ Lp. bl.	10Lp+B	65	18.5	29.5	II	0.64	220	3.4
5	C_2/ Lp. ox.	6Lp2Pn1B1P+Sp	45	19.0	22.0	I	0.62	160	3.6
6	D_2/ Lp. ox.	7Lp2O1B	55	21.0	22.0	I	0.73	220	4.0

Table 2

Soil grading of soils

SP	Genetic horizon	Horizon thickness, cm	Analysis results of soils granulometric composition							Horizon name according to the content of physical clay
			>3	3.0–1.0	1.0–0.5	0.50–0.25	0.25–0.05	0.05–0.01	<0.01	
1	A_1	3–35	–	2.5	18.5	21.1	29.1	10.5	18.3	Cohesive sandy loam
	A_2B_1	36–81	1.2	1.1	15.3	25.4	28.0	14.6	14.4	Loose sandy loam
	B_2	82–120	–	0.6	33.5	26.4	32.0	3.1	4.4	Loose sand
	D	121–200	–	0.9	16.3	13.8	15.5	28.6	24.9	Light loamy soil
2	A_1	3–35	2.0	5.6	35.2	27.3	19.4	4.3	6.2	Cohesive sand
	A_2B_1	36–56	4.2	6.3	32.2	23.1	18.6	7.3	8.3	Cohesive sand
	B_2	57–88	4.8	8.2	21.3	23.8	28.5	5.6	7.8	Cohesive sand
	B_{3g}	89–200	3.1	3.9	18.5	25.9	33.3	6.4	8.9	Cohesive sand
3	A_1	3–18	2.6	4.9	33.8	29.4	16.3	5.9	7.1	Cohesive sand
	A_2	19–58	3.0	5.4	31.2	24.7	15.7	11.8	8.2	Cohesive sand
	B_{1g}	59–124	4.2	5.0	24.9	28.6	22.8	6.9	7.6	Cohesive sand
	B_{2g}	125–200	3.4	5.2	26.8	32.6	14.1	8.5	9.4	Cohesive sand
4	A_1	4–29	5.6	2.2	8.9	22.4	17.5	26.1	17.3	Cohesive sandy loam
	A_2B_1	30–65	1.0	0.9	16.2	24.1	28.1	11.9	17.8	Cohesive sandy loam
	B_{2g}	66–144	1.2	3.2	25.5	25.3	18.4	9.7	16.5	Cohesive sandy loam
	D_g	145–200	1.1	1.8	15.9	18.7	12.6	22.6	27.3	Light loamy soil
5	A_1	3–31	1.2	5.9	6.7	35.5	37.7	1.0	12.0	Loose sandy loam
	A_2B_1	32–62	–	0.9	2.2	15.7	57.7	7.2	16.3	Cohesive sandy loam
	B_2	63–105	1.0	3.0	2.7	18.0	55.1	5.9	14.3	Loose sand
	B_3	106–200	–	1.4	28.0	9.7	49.6	0.5	10.8	Loose sandy loam
6	A_1	3–23	–	0.7	8.8	12.6	11.4	45.3	21.2	Light loamy soil
	A_2B_1	24–46	–	0.6	5.8	13.2	8.4	48.6	23.4	Light loamy soil
	D_1	47–125	–	–	3.2	6.4	14.5	42.4	33.5	Average loamy soil
	D_2	126–200	–	–	2.8	12.3	8.8	41.0	35.1	Average loamy soil

Lime trees plantations under study grow on the following soils (Table 2): SP 1 – sod-podzol light-podzolic sabulous, on cohesive sandy loam, replaced by loose sandy loam and lower byloose sand, and from the depth of 121 cm by loamy soil, moraine; SP 2 – sod-podzol light-podzolic gleized sabulous below, on cohesive sand, moraine; SP 3 – sod-podzol medium-podzolic temporarily excessively wet sabulous, on cohesive sand; SP 4 – sod-podzol light-podzolic temporarily excessively wet sabulous, on cohesive sandy loam, moraine, replaced by loamy soil, moraine from the depth of 145 cm; SP 5 – sod-podzol sabulous, on loose sandy loam with sand layers; SP 6 – sod-podzol light-podzolic loamy, on loamy soil, loess-like, spread by middle loam.

Soils are characterized by well-developed humus horizon (up to 35 cm), there are signs of becoming podzolic. The humus content (Table 3) in the top (humus) horizon varies from 1.37 to 4.04%. In podzol-illuvial and podzolic horizons the humus content decreases dramatically and varies within 0.11–0.85%. The greatest humus content is noted in the oxalis lime-tree forest in the mixed plantation of artificial origin (SP 5), the lowest – in the pure lime tree cultures, type of conditions of growth place is the bilberry lime-tree forest, C_3 (SP 4).

According to pH value the soils on the analyzed sample plots are mainly characterized by medium- and low-acidic medium reaction. Soils on SP 6 (TOFC – D_2, oxalis lime-tree forest) are characterized by strong-acidic medium reaction.

The value of hydrolytic acidity in the soils under study varies from 0.89 to 9.01 mg-eq on 100 g of soil, and that is defined by soil grading, humus content and development of process of podzol formation. The highest hydrolytic acidity is noted in the humus horizon presented by light loamy soil (SP 6) in oxalis growth conditions. With depth, as a rule, hydrolytic acidity naturally drops, and that points out to reduction of hydrogen and aluminium ions content in the soil absorptive complex.

Phosphorus mobile forms content varies within large limits in genetic horizons. The average content of phosphorus mobile forms on the sample plots varies from 5.3 to 10.3 mg on 100 g of soil. Humus horizons of SP 1, 2 belong to the increased according to the phosphorus supply degree group and also podzol-illuvial horizons of SP 2 and 6, i. e. in oxalis and brake types of forest.

Table 3

Agrochemical characteristic of soil

SP	genetic horizon	Analysis results of soils agrochemical properties of lime-tree stands									
		humus content, %	pH in KCl	hydrolytic acidity according to Kappen, mg-eq 100 g of soil	P_2O_5	K_2O	Fe_2O_3	Ca^{2+}	Mg^{2+}	absorption capacity	soils degree of saturation by bases, %
					mg on 100 g of soil			mg-eq 100 g of soil			
1	A_1	2.61	5.21	3.85	16.8	9.2	5.7	3.90	1.98	9.73	60.4
	A_2B_1	0.25	5.20	2.62	7.5	3.4	3.5	2.48	2.40	7.50	65.1
	B_2	–	5.24	1.66	3.1	2.4	2.2	1.24	1.80	4.70	64.7
	D	–	5.13	1.03	3.3	3.8	3.4	3.26	3.19	7.48	86.2
2	A_1	2.42	6.25	2.77	14.0	14.4	3.1	8.04	4.52	15.33	81.9
	A_2B_1	0.22	6.00	1.40	16.5	12.9	5.5	6.02	0.50	7.92	82.3
	B_2	–	5.31	5.00	1.8	7.8	2.6	11.00	20.60	36.6	86.3
	B_{3g}	–	6.00	2.10	8.9	3.8	2.9	8.21	11.45	21.76	90.3
3	A_1	2.40	5.42	3.82	11.4	3.4	3.2	3.81	5.62	13.25	71.2
	A_2	0.38	5.84	1.22	8.6	5.7	4.1	4.83	7.41	13.46	90.9
	B_{1g}	–	6.00	1.41	10.2	2.7	2.1	7.15	10.30	18.86	92.5
	B_{2g}	–	5.11	1.33	8.6	2.9	2.5	11.23	9.18	21.74	93.9
4	A_1	1.37	4.89	5.10	8.8	2.6	5.6	8.66	4.90	18.66	72.7
	A_2B_1	0.11	5.11	2.63	6.2	4.8	1.8	5.11	6.82	14.56	81.9
	B_{2g}	–	5.33	1.88	3.4	6.4	2.4	4.18	7.15	13.21	85.8
	D_g	–	5.35	1.66	2.9	5.9	3.6	3.98	3.89	9.53	82.6
5	A_1	4.04	5.41	4.11	9.1	6.3	5.5	5.54	3.66	13.31	69.1
	A_2B_1	0.46	5.63	2.06	9.8	2.8	6.0	4.00	4.00	10.06	79.5
	B_2	–	5.75	1.11	2.3	4.3	2.3	2.20	2.28	5.59	80.1
	B_3	–	5.91	0.89	3.1	5.7	3.3	4.21	2.10	7.20	87.6
6	A_1	2.03	4.27	9.01	3.0	2.2	1.8	2.12	1.64	12.77	29.4
	A_2B_1	0.85	4.58	5.16	14.0	2.2	9.0	1.24	1.40	7.80	33.8
	D_1	–	4.51	3.18	6.2	4.0	6.6	4.07	4.19	11.44	72.2
	D_2	–	4.83	2.80	5.3	2.4	4.8	3.28	2.08	8.16	65.7

Metabolic potassium content is from 2.2 to 14.4 mg on 100 g of soil for the soils on the analyzed sample plots. The lowest content of metabolic potassium is observed in humus and podzol-illuvial horizon in the oxalis lime-tree forest (TOFC – D_2), the highest one – in humus horizon in the brake lime-tree forest (TOFC – B_2). The highest average content of metabolic potassium for all horizons on the sample plots is noted in brake types of forest in the mixed lime-tree plantation (SP 2), the lowest – in oxalis lime-tree forest in the mixed plantation with the age of 55 years (SP 6).

Mobile iron content varies from 1.8 to 9.0 mg on 100 g of soil. The highest quantity is found in a podzol-illuvial horizon on loam soils in the oxalis type of forest (SP 6).

The highest average quantity of exchangeable cations of calcium and magnesium is in the soils of SP 2, 3 and 4 where lime-tree plantations in the brake and bilberry types of forests grow. In the oxalis lime-tree forests the quantity of exchangeable cations of calcium and magnesium is much lower and varies from 2.64 to 9.20 mg-eq on 100 g of soil.

Calculation of results of soil saturation by bases shows that the top horizons (humus and podzol-illuvial) of SP 6 are poor in bases and in their soil absorptive complex the mobile ions of hydrogen and aluminium prevail, and that speaks about the intensive nature of podzol formation processes. Degree of saturation of soil horizons by bases on the other sample plots is rather high and varies from 60.4 to 93.9%.

Conclusion. Study of soil growth conditions of lime-tree plantations showed that the soils are presented by sandy loams on sandy loam (SP 5), by sandy loams with loamy soil underneath (SP 1, 4), sands (SP 2, 3) and loamy soils (SP 6). According to supply of humus in the top soil horizon in oxalis lime-tree forests they fall into low, middle and rather high groups, in bilberry lime-tree forests – to low and middle, in brake lime-tree forests – to middle group. According to soil acidity on SP 6 (oxalis lime-tree forest) they are characterized by strong acidic reaction of medium, soils of other plantations – by middle and low acidic. According to phosphorus supply soils fall into I–IV groups. The highest quantity of mobile forms of phosphorus is found in the brake lime-tree forest of natural origin. Soils in the brake lime-tree forest belong to the middle group according to the potassium supply level, soils of other plantations – to very low and low. The highest content of mobile iron is observed in podzol-illuvial horizon on SP 6 (oxalis lime-tree forest), the lowest – in humus and podzol-illuvia horizon on SP 6 (oxalis lime-tree forest), the lowest – in humus and podzol-illuvial horizon on SP 4 (bilberry lime-tree forest) and 6. The highest quantity of exchangeable cations of calcium and magnesium are in the soils in brake and bilberry types of forest.

Productivity and composition of lime-tree plantations depend on many factors, one of which is soil fertility which can be determined by species composition and quantitative indicators of growing vegetation. Plantations growing on sandy loams and loamy soils in oxalis lime-tree forests have higher values of average annual increase on reserve, grow according to the I^{st} quality class. Soils are saturated with humus in a higher degree (belong to middle and rather provided groups), but in a lower – with nutrients, such as phosphorus (belong to low and middle supply groups) and potassium (belong to very low and low supply groups), they have middle and low acidic reaction of soil medium. Plantations growing on sends in brake and bilberry types of forests have smaller indexes of average annual increase, grow according to the I^{st} and II^{nd} quality classes. Soils are characterized by low acidic reaction of soil medium, belong to middle group according to supply of phosphorus and potassium.

References

1. Yakimov N. I., Prakhodskiy A. N., Nosnikov V. V., Volkovich A. P. Technology of restoration plantings of Acer platanoides and Tilia cordata *Mill. Trudy BGTU* [Proceedings of BSTU], series I, Forestry, 2008, issue XVI, pp. 201–203 (In Russian).

2. Yurkevich I. D., Aderikho V. S., Dol'skiy V. L. *Lipnyaki Belorussii* [Linden of Belarus]. Minsk, Nauka i tekhnika Publ., 1988. 174 p.

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