Phenological forms of aspen in the Central Black Earth region of European Russia

A P Tsarev1*, N V Laur2 and V A Tsarev1

1 Laboratory of Forest Tree Breeding, Federal State Budgetary Institution “All-Russian Research Institute of Forest Genetics, Breeding and Biotechnology”, 105 Lomonosov Street, Voronezh 394087, Russian Federation
2 Forest Engineering Faculty, Federal State Budgetary Educational Institution “Petrozavodsk State University”, 33 Lenin avenue, Petrozavodsk 185910, Russian Federation

*Corresponding email: E-mail: antsa-55@yandex.ru

Abstract. The main purpose of this work is to define the biological and economic features of various phenological forms of aspen. The research objectives were to visualize the early budbreaking (E), the late budbreaking (L) and the intermediate budbreaking (I) aspen phenological forms and to study the differences in prevalence of heart rot attack, productivity and quality of wood stock, and timber density. The research methodology included stationary and route observations. Stationary surveys were conducted on 4 pairs of trial areas in the C2 and D3 forest types. It is observed 620 allotments (total area 823.1 ha). It was found that budbreaking of the E-forms began in for 7-14 days earlier than of the L-forms. The prevalence of heart rot attack among the L-forms was by 30-40 % less, than among the E-forms. The stem quality of the L-forms was higher by 14-50 %. The timber density of the L-forms is reliability higher than of the E-forms.

1. Introduction
The area of Aspen (Populus tremula L.) stands in Russia ranks the first place in the world (about 25 million hectares) [1, 2]. In this vast territory, aspen has a very multiform structure. It has many different forms (by the color of the bark, by the shape of the crown, by the stem straightness, growth rapidity, heart rot steadiness etc.) [3-17].

Among them there are of interest the phenological forms, different at the beginning of the growing season in spring. For the first time the presence of early budbreaking (E) and late budbreaking forms (L) in Russia was described for oak [18]. Further study of these forms had involved a large group of domestic researchers [19-22]. By analogy with the oak tree, was to be expected that different phenoforms can be define from the other tree species that may have some importance in their cultivation.

The presence of early and late budbreaking forms of aspen reported by different researchers [23-28]. Their prevalence and biological features were studied. But due to the vastness of the area, in each region there are some features of these forms, the study of which will allow developing more rational ways of their cultivation and use.
The purpose of the research undertaken in this work was to clarify some biological features and practical significance of early and late budbreaking forms of aspen in the Central Black Earth region of European Russia.

2. Materials and Methods
The objects of research were the aspen native stands situated on the mountainous part of the Right bank of the Voronezh River in the area of the Educational Research Forestry of Voronezh State Forestry Engineering University named after G F Morozov. The research methodology was consist in visualize survey all of the aspen sites in the Right bank. The registered cards were prepared for each site included the indicators of interest to researchers, some of which were taken from the inventory descriptions, and the others were determined in the field.

Phenological forms of aspen were identified on the basis of stationary and route observations. The stationary observations were carried out in 4 pairs of the trial areas in $C_3$ and $D_3$ forest types either in the early or in the later phenoforms aspen stands, and route observations were carried out in the aspen native stands situated on the Right bank of the Voronezh River in the area of the Educational Research Forestry of Voronezh State Forest Technical University on 620 allotments (total area 823.1 ha). In these surveys it was found that the early budbreaking forms began to unfold the leaves in 7-14 days earlier than the late budbreaking forms (Figure 1).

![Figure 1. Phenological forms of aspen: in the foreground there are the late budbreaking forms, behind it – the early budbreaking forms. The Right-bank forest in Educational Research Forestry of Voronezh State Forestry Engineering University named after G F Morozov. Photo by A P Tsarev.](image)

A certain part of the aspen occupied an intermediate position. Therefore, all aspen stands were divided into early budbreaking (E), late budbreaking (L) and intermediate (I) budbreaking forms.
3. Results and discussion

Differences in the beginning of budbreaking in different aspen phenoforms related to the amount of accumulation of effective temperatures ($\Sigma_{t_{ef}} > 5$ °C) and the nature of the spring period. On average, the sum of effective temperatures for E-forms was 92-103 °C, and for L-forms it ranged from 171 to 189 °C. I.e. the beginning of this phenological phase for the aspen L-forms required the sum of effective temperatures in 1.8-1.9 times more than for the E-forms. For the L- and the E-forms of oak, such ratios in Voronezh region were higher and amounted to 2.0-2.5 [20].

The study of the aspen stands distribution by the relief’s elements showed a trend of different timing of the E- and the L-forms (Table 1).

| Aspen phenoforms | Distribution of the aspen stand areas by the relief’s elements (%) |
|------------------|---------------------------------------------------------------|
|                   | watershed slopes | watersh ed | saucer-form lowerings | peaks of the gullies | hollows of the gullies | slopes of the gullies | thalwegs of the gullies |
| Early            | 55.7             | 19.8       | 0.8                  | 2.3                 | 7.7                  | 3.1                  | 8.3                  | 2.3                 |
| Intermediate     | 30.2             | 15.4       | 1.3                  | 0.4                 | 9.4                  | 2.2                  | 30.3                 | 10.8                |
| Late             | 26.9             | 5.1        | 0.9                  | 1.9                 | 7.9                  | 2.8                  | 14.0                 | 4.1                 |
| Total:           | 49.9             | 18.5       | 0.9                  | 1.9                 | 4.0                  | 2.8                  | 14.0                 | 4.1                 |

The data of the Table 1 shows that the E-forms tends to the higher terrain (watershed, watersh ed slopes, the peaks of the gullies, the upper part of the gullies slopes), and the L-forms inhabits the lower location (the hollows of the gullies, the lower parts of the gullies slopes, the thalwegs of the gullies). This is due, apparently, to the fact that the late forms of aspen, like ones of oak, more suited to frost and moist places [19, 20, 21]. A similar trend is observed in the distribution of aspen stands by the types of growth conditions (Table 2).

| Aspen phenoforms | Distribution of the aspen stand areas by the types of growth conditions (%) |
|------------------|-----------------------------------------------------------------------------|
|                   | B_2  | B_3  | C_2  | C_3  | C_4  | D_2  | D_3  | D_4  |
| Early            | 13.8 | 2.3  | 61.3 | 2.9  | –    | 15.7 | 3.9  | 0.10 |
| Intermediate     | 24.6 | 4.5  | 37.8 | 11.1 | –    | 4.2  | 17.8 | –    |
| Later            | 12.4 | 4.7  | 19.7 | 43.1 | 1.30 | 2.6  | 16.2 | –    |
| Total:           | 15.9 | 2.8  | 56.1 | 5.1  | 0.04 | 13.1 | 6.9  | 0.05 |

We have traced some qualitative and morphological features of these aspen forms. Thus, in the assessment of aspen lesions the percentage of trees over the age of 30 years with the presence of *Fomes igniarius* Fr. fruit bodies was determined. This fungus causes aspen heart rot.

On the whole, according to the studied array it was found that the number of trees with fruit bodies of the fungus in the E-forms was 31.5 %, in the I-forms – 27.3 %, and in the L-forms – 20.5 %. More detailed data for the aspen stands with the same growing conditions and the closed age are presented in the Table 3. Based on the data obtained, it can be concluded that the L-forms seems to be more resistant to infection than the E-forms.

Research of the aspen trees’ E- and L-forms productivity and quality is carried out on 4 pairs of trial areas (Table 4). Analysis of the data in Table 4 showed that in the same age and under the same growth conditions differences (in terms of conventional stock) in stocks between E- and L-forms range from 2 to 14 m³ (0.5-4.5 %).
Table 3. The prevalence of heart rot among the various aspen phenoforms.

| №№ of the trial areas | Aspen phenoforms | Type of the forest / the age, years | Healthy stems, % | Infected stems, % by the heart rot | Infected stems, % by other pathogenic factors |
|------------------------|------------------|------------------------------------|------------------|------------------------------------|-----------------------------------------------|
| 20                     | E                | C/44                               | 63               | 28                                 | 9                                             |
| 19                     | L                | C/44                               | 66               | 24                                 | 10                                            |
| II pair of the trial areas |                |                                    |                  |                                    |                                               |
| 34                     | E                | C/39                               | 77               | 21                                 | 2                                             |
| 9                      | L                | C/43                               | 84               | 6                                  | 10                                            |
| III pair of the trial areas |            |                                    |                  |                                    |                                               |
| 15                     | E                | D/35                               | 87               | 13                                 | 0                                             |
| 22                     | L                | D/36                               | 93               | 4                                  | 3                                             |
| IV pair of the trial areas |            |                                    |                  |                                    |                                               |
| 23                     | E                | D/50                               | 42               | 58                                 | 0                                             |
| 16                     | L                | D/43                               | 55               | 44                                 | 1                                             |

With due account taken of the fact that when estimating a growing forest the error of measurement for individual trees can be as high as 15-20 % [29], these differences can be considered insignificant. On the other hand, the difference in stocks of the high quality trunks is much higher and ranges from 7 to 34 m$^3$ (i.e. 17-94 %) in favor of the L-form.

Table 4. The productivity and quality of stands among the various aspen phenoforms.

| № of the trial areas | Aspen phenoforms | Type of the forest / the age, years | Actual wood stock, m$^3$ | Conventional stock$^a$, m$^3$ | Stock of high quality trunks, % |
|---------------------|------------------|------------------------------------|--------------------------|--------------------------------|--------------------------------|
|                     |                  |                                    | total                    | including aspen               |                                |
| I pair of the trial areas |                |                                    |                          |                                |                                |
| 20                  | E                | C/44                               | 311                      | 260                            | 324                            | 41                             |
| 19                  | L                | C/44                               | 279                      | 215                            | 310                            | 48                             |
| II pair of the trial areas |            |                                    |                          |                                |                                |                                |
| 34                  | E                | C/39                               | 207                      | 132                            | 253                            | 36                             |
| 9                   | L                | C/43                               | 186                      | 183                            | 341                            | 70                             |
| III pair of the trial areas |          |                                    |                          |                                |                                |                                |
| 15                  | E                | D/35                               | 234                      | 190                            | 379                            | 55                             |
| 22                  | L                | D/36                               | 163                      | 101                            | 393                            | 71                             |
| IV pair of the trial areas |            |                                    |                          |                                |                                |                                |
| 23                  | E                | D/50                               | 251                      | 225                            | 368                            | 46                             |
| 16                  | L                | D/43                               | 283                      | 231                            | 366                            | 55                             |

$^a$ – the wood stock of the pure aspen stands with fullness of 1.0 in the age of 45 years

The next factor being studied is the density of wood. It’s one of the main indicators of the timber quality, which is also applicable to aspen [30]. Research of the aspen trees’ E- and L-forms timber quality is also carried out on 4 pairs of trial areas (Table 5).

From the data of the table 5 it can be seen that the timber density is significantly higher in stands with the late budbreaking aspen forms. The difference ranges from 19 to 36 kg/m$^3$, or from 4.3 to 6.5 %.
Table 5. The timber density of the various aspen phenoforms.

| №№ of the trial areas | Aspen phenoforms | Type of the forest / the age, years | Number of the measurements | Timber density, kg/m$^3$ $\bar{X}$$\pm$$S$ | distinction reliability, $t$ |
|-----------------------|------------------|-----------------------------------|---------------------------|------------------------------------------|---------------------------|
| 20                    | E                | C$_2$/44                           | 18                        | 488$\pm$7.1                             | 2.64                      |
| 19                    | L                | C$_2$/44                           | 18                        | 514$\pm$6.8                             |                           |
| 34                    | E                | C$_2$/39                           | 18                        | 480$\pm$7.4                             | 3.23                      |
| 9                     | L                | C$_2$/43                           | 18                        | 511$\pm$6.3                             |                           |
| 15                    | E                | D$_3$/35                           | 18                        | 440$\pm$10.1                            | 1.41                      |
| 22                    | L                | D$_3$/36                           | 18                        | 459$\pm$9.0                             |                           |
| 23                    | E                | D$_3$/50                           | 18                        | 432$\pm$5.8                             | 4.10                      |
| 16                    | L                | D$_3$/43                           | 18                        | 468$\pm$6.6                             |                           |

The data obtained from the study of wood stock and timber quality of different phenological forms of aspen can be used in the production for the cultivation of healthy high quality wood of this breed.

4. Conclusions

Thus, studies of the different phenological (early budbreaking, intermediate and late budbreaking) forms of aspen in the Central Black Earth region allowed drawing the following conclusions.

- The difference in the timing of budbreaking in the studied forms of aspen, varies depending on the weather conditions of spring, from 6-7 to 13-14 days; and the late forms requires the sum of the effective temperatures for the beginning of this phenophase in 1.8-1.9 times more than the early ones.
- In the research region under the upland oak forest conditions there was founded that the L-forms inhabit mostly low places of relief and wetter types of forest than the E-forms.
- Studies of the aspen stands of a similar age located under the same growth conditions showed that the percentage of the trees affected by heart rot is less in for 30-40 % in the L-forms stands in comparison with the E-forms.
- The E- and L-forms stands of aspen under the same growth conditions did not show a significant difference in the total stock of wood. However, the stock of high quality trunks is higher (by 14-50 %) in the L-forms stands.
- The timber density in L-forms stands is reliability higher than in E-form.
- The studied properties of the late budbreaking and the early budbreaking forms of aspen allow more purposefully searching for valuable forms of aspen. They point us to take into account the established facts when choosing the ecotypes of aspen for various conditions of its cultivation.

Acknowledgments

The authors express their gratitude to Professor of the Voronezh Forest Technical Institute M M Veresin and other researchers for pioneering works on the study of various phenoforms of woody plants, including aspen trees in various regions of the European territory of the former USSR, as well as leading researcher of the All Russian Research Institute of Forest Genetics, Breeding and biotechnology R P Tsareva for providing archival materials.

References

[1] State Forest Register 2013 (as of January 1, 2014) 2014 [In Russian – Gosudarstvennyj lesnoj reestr 2013 (po sostoyaniyu na 1 yanvarya 2014 g.)] (Moscow: RusForestInfOrg [In Russian – Roslesinforg]) pp 690
[2] Tsarev A P, Laur N V 2016 Dynamics of species composition of the Forest Fund of the Russian Federation [In Russian – Dinamika porodnogo sostava lesnogo fonda RF] In Proc. All-Russian Scie.&Pract. Conf. with Intl. particip. dedicated to the 65th anniversary of higher forest education in the Republic of Karelia: Improving the efficiency of the forest complex [In Russian – Materialy Vserossijskoj nauchno-prakticheskoj konferencii s mezhdunarodnym uchastiem, posvyashchennoj 65-letiyu vysshego lesnogo obrazovaniya v Respublike Kareliya: Povyshenie effektivnosti lesnogo kompleksa] (Petrozavodsk: Publishing House of Petrozavodsk State University [In Russian – PetrGU]) pp 276-279

[3] Dvoreckij M L 1940 About forms of aspen [In Russian – O formah osiny] In Sci. Works of Tatar Forest Research Station of All-Soviet Research Institute of Forestry [In Russian – Trudy Tatarskoj LOS VNIILHa] vol. 5 Issue [vyp.] 5 pp 55-58

[4] Y'Ablokov A S 1941 Gigantic form of aspen in the forests of the Soviet Union [In Russian – Izpolinskaya forma osiny v lesah SSSR] In Works of All-Soviet Research Institute of Forestry [In Russian – Trudy VNIILHa] Issue [vyp.] 23 pp 52

[5] Y'Ablokov A S 1963 Breeding and reproduction of healthy aspen [in Russian – Vospitanie i razvedenie zdorovoj osiny] (Moscow: State Forest&Paper Publishing house [In Russian – Goslesbumizdat]) pp 443

[6] Orlenko E G 1957 The main forms of aspen in the forests of the BSSR and their use in forestry [In Russian – Osnovnye formy osiny v lesah BSSR i ih ispol'zovanie v lesnom hozyajstve] J. Forestry [In Russian – Lesnoe hozyajstvo] 5 pp 7-11

[7] Ivannikov S P 1959 Aspen breeding in the forest-steppe on the speed of growth, resistance to rot and the quality of wood [In Russian – Selekiya osiny v lesostepi na bystrotu rosta, ustojchivost' protiv gnili i kachestvo drevesiny] In Sci. Works of All-Union Research Institute of Silviculture and Mechanization of Forestry: Experience and achievements in breeding for selection of forest species [In Russian – Works VNIILM: Opyt i dostizheniya po selekcii lesnyh porod] Issue [vyp.] 38 pp 63-124

[8] Bogdanov P L 1965 Poplars and their culture [In Russian – Topolya i ih kul'tura] Moscow: Forest industry [In Russian – Lesnaya promyshlennost'] pp 104

[9] Danilin M A 1965 Forms of aspen of the South-Western part of the Eastern Sayan [In Russian – Formy osiny yugo-zapadnoj chasti Vostochnogo Sayana] Novosibirsk: Siberian Technology Institute [In Russian – Tr. Sib. Tekhnol. In-ta] pp 40

[10] Wühlisch G von 2006 Ergebnisse der Züchtung von Pappeln und Aspen in Großhansdorf. Perspektiven für die Energie – und Rohstoffezeugung [In German] In Vortr. Pflanzenzüchtung Großhansdorf vol. 70 pp 157-172

[11] Meyer M 2010 Trockenheitreaktion und Holzanatomische Eigenschaften der Zitter-Pappel (Populus tremula L.) [In German] Physiologie und QTL-Mapping. Dissertation zur Erlangung des akademischen Grades Doctor rerum silvicarum. Dresden den 02 Juni 2010 pp 147

[12] Tsareva R P 2014 Aspen breeding [In Russian – Selekiya osiny] in Tsarev A P, Pogiba S P and Laur N V Forest and ornamental tree species’ breeding [In Russian – Selektsiya lesnykh I dekorativnykh drevesnykh rastenij] eds by A P Tsarev (Moscow Forest State University Publishing house) pp 350-363

[13] Hofmann M and Janßen A 2016 Genetic Improvement of Poplar and Prospects for Poplar Cultivation in Germany [electronic resources] Abstr. of submitted papers on the 25th Session of the Int. Poplar Commission in Berlin, (Germany) (Working Paper IPC/14 Forestry Policy and Resources Division, FAO, Rome) p 39 URL: http://www.fao.org/forestry/ipc/69946/en

[14] Bojtsov A K, Zhigunov A V, Grigor'ev A A and Bondarenko A S 2018 Evaluation of prospects of poplar hybrid clones and aspen using for forest plantation in the North-West of Russia [In Russian – Otsenka perspektivnosti ispolzovaniya klonov gibridnykh topolei i osiny dljaoplantatsionnogo lesovyrschivaniya v uslovijakh Severo-Zapada Rossii] Proc. Int. Conf. on Forests of Russia: politics, industry, science, education [Materialy mezhdunarodnoj
konferencii “Lesa Rossii: politika, promyshlennost’, nauka i obrazovanie)” [vol 1] ed V M Ged’o (St. Petersburg: St. Petersburg State Forest Engineering University) [In Russian – Gosudarstvennyj lesotekhnikheskij universitet (SPbGLTU)] pp 40-43

[15] Chernichenko O, Rumyantsev D and Sirotova A 2018 Aspen clonal sustainability assessment in natural populations tree-ring based information [electronic resources] Proc. German Russian Conf. on Forest Genetics 21-23 November 2017 [Degen Bernd, Krutovskiy Konstantin V., Liesebach Mirko (eds)] Ahrensburg (Braunschweig/Germany): Thünen Report 62 October 2018 pp 17-22 DOI: 10.3220/REP1539855736000 (Johann Heinrich von Thünen-Institut, 148 pp.) URL: https://www.thuenen.de/en/info-desk/publications/thuenen-report-thuenen-report-all-issues/

[16] Tsarev A, Tsareva R, Tsarev V, Fladung M and Wühlisch G von 2018 Aspen Hybridization: Parents’ Compatibility and Seedlings’ Growth J. Silvae Genetica 15 Mar. 2018 vol. 67 Issue 1 pp 12-19 [electronic resources] Eds. by the Thünen Institute of Forest Genetics (Großhansdorf, Germany) De Gruyter Open Berlin (Germany) | DOI: https://doi.org/10.14788/sg-2018-0002

[17] Zhigunov A V, Ulanich P S, Lebedeva M V and Potokina E K 2018 Development of research resources for marker-assisted selection of aspen (Populus tremula L.) in Russia [electronic resources] Proc. German Russian Conf. on Forest Genetics 21-23 November 2017 [Degen Bernd, Krutovskiy Konstantin V., Liesebach Mirko (eds)] Ahrensburg (Braunschweig/Germany): Thünen Report 62 October 2018 pp 35-39 DOI: 10.3220/REP1539855736000 (Johann Heinrich von Thünen-Institut, 148 pp.) URL: https://www.thuenen.de/en/info-desk/publications/thuenen-report-thuenen-report-all-issues/

[18] Chernyaev V M 1858 About the forests of Ukraine. Speech delivered at the solemn meeting of Kharkiv University on September 1, 1857 [In Russian – O lesah Ukrainy. Rech’, proiznesyonnaya v torezhestvnom sobranii Har’kovskogo universiteta 1 sentyabrya 1857 g] Moscow pp 54

[19] Pyatnichk S S 1941 Ecological types of the Common oak (Quercus robur L.), and their use in silvicultural practice [In Russian – Ekologicheskie tipy obyknovennogo duba i ih ispol’zovanie v lesokul’turnoj praktike] Moscow: J. Forestry [In Russian – Lesnoe hozyaystvo] 3 pp 16-17

[20] En’kova E I 1950 Territorial placement of early and late budbreaking forms of the English oak (Quercus robur L.) [In Russian – Territorial’noe razmeshchenie rano i pozdno raspuskayushchihsiya form duba chereshchatogo] Moscow: Reports of the USSR Academy of Sciences (New series) [In Russian – Doklady AN SSSR (Novaya seriya)] Vol. LXXIV 1 pp 139-142

[21] Veresin M M 1958 On physiologic forms of pedunculate oak (Quercus robur L.) and their use in afforestation [In Russian – O fiziologicheskih formah duba chereshchatogo i ispol’tzovanie ih v lesorazvedenii] J. PHHEI (Publishing House of Higher Education Institutions) “Forest Magazine” [In Russian – IVUZ (Izdatel’stvo Vysshih Uchebnyh Zavedenij) “Lesnoj Zhurnal”) No 3 (Arkhangel’sk: Arhangel’sk State Forest Technical Institute [In Russian - Arhangel’skij Gosudarstvennyj Lesotekhnikheskij Institut]) pp 3-16

[22] Shutyayev A M 2007 50 years of geographical cultures of oak-trees, originated by the program of the academician A.S. Yablokov [In Russian – 50 let geograficheskim kulturam duba chereshchatogo, zalozhennym po programme akademika A.S. Yablokovaja] Coll. Sci. Works: Preservation, study and reproduction of genetic resources of forest woody plants: Collection of scientific works [In Russian – Sohranenie, izuchenie i vosproizvodstvo geneticheskih resursov lesnyh drevesnyh rastenij: Sbornik nauchnyh trudov] Voronezh: NiiIgiS pp 63-68.

[23] Kruglikov G G 1938 On a new form of aspen trees [In Russian – O novoj forme osiny] Moscow: J. Forestry [In Russian – Lesnoe hozyaystvo] 6 pp 74-75

[24] Danilov M D 1954 Early and late budbreaking forms of aspen [In Russian – Rano i pozdno raspuskayushchayasya formy osiny] Moscow: Bulletin of the Moscow society of nature
testers (New series) The Department of biology [In Russian – Byulleten’ Moskovskogo obshchestva ispytatelej prirody (Novaya seriya) Otdel biologii] vol. LIX issue 5 pp 23-29

[25] Orlenko E G 1958 The form variety of aspen in the forests of the Belarussian SSR and the possibility of its use in breeding [Formovoe raznoobrazie osiny v lesah Belorussskoj SSR i vozmozhnosti ego ispol’zovaniya v selekcii] Coll. Sci. Works of All-Union Research Institute of Siviculture and Mechanization of Forestry (AURISMF): “Fast-growing and economically valuable wood species” [In Russian – SB. Tr. Vsesojusnogo nauchno-issledovatel’skogo instituta lesovodstva i mekhanizacii lesnogo hozyaystva (VNIILM): “Bystrorastushchie i hozyaystvenno cennye drevesnye porody”] Moscow: VNIILM pp 7-11

[26] Pyatrouski P YA 1962 On forms of aspen in the forests of the North-West part of Belorussian SSR (Soviet Socialist Republic) [In Belorussian – Ab formah asiny u lyasah paunochna uskhodnyaj chastki BSSR] Minsk: Bulletin of the Academy of Sciences of the BSSR, ser. Biyal. N. [In Belorussian – Vesi AN BSSR (Akademii Nauk BSSR), ser. Biyal. N.] No 1

[27] Smilga Ya Ya 1965 Economic evaluation of aspen different biological forms [In Russian – Hozyaystvennaya ocenka osiny raznyh biologicheskih form] Moscow: J. Forestry [In Russian – Lesnoe hozyaystvo] 8 pp 12-17

[28] Tsarev A P 1968 To the characteristic of early and late budbreaking forms of aspen in the Central forest-steppe [In Russian – K karakteristike rano i pozdnno raspuskayushchihsy form osiny v Central’noj lesostepi] J. PHHEI (Publishing House of Higher Education Institutions) “Forest Magazine” [In Russian – IVUZ (Izdatel’stvo Vysshikh Uchebnyh Zavedenij) “Lesnoj Zhurnal”] No 6 (Arkhangel’sk: Arhangelsk State Forest Technical Institute [In Russian - Arhangel’skij Gosudarstvennyj Lesotekhnicheskij Institut]) pp 33-37

[29] Zakharov V K 1961 Forest taxation [In Russian – Lesnaya taksaciya] (Moscow: Publishing house “Higher School” [In Russian – Izdatel’stvo Vysshaya Shkola]) pp 360

[30] Poluboyarinov O I 1976 Density of wood [In Russian – Plotnost’ drevesiny] (Moscow: Publishing house “Forest Industry” [In Russian – Izdatel’stvo “Lesnaya Promyshlennost’”]) pp 160