поглощение углекислоты и способствующие выживанию данного подвида в условиях стресса. В период почвенной и атмосферной засухи карельская береза более эффективно по сравнению с березой повислой использовала низкую солнечную радиацию, что выражалось в высокой скорости насыщения световой кривой. Это же обнаружилось и в пасмурные дни при хорошей водообеспеченности. Активное поглощение углекислоты в ранние утренние часы и в пасмурную погоду, особенно в условиях атмосферной засухи, позволяет поддерживать углеродный баланс на приемлемом уровне, и повышает ее конкурентоспособность.

ЛИТЕРАТУРА

1. *Болондинский В.К.* Исследование зависимости фотосинтеза от интенсивности солнечной радиации, температуры и влажности воздуха у растений карельской березы и березы повислой // Труды Карельского научного центра Российской академии наук. 2010. № 2. С.3–10.

2. *Болондинский В.К., Виликайнен Л.М.* Моделирование световых кривых у берез Betula pendula Roth. (P) и Betula pendula Roth. f. carelica (C) // Математическое моделирование в экологии. Пущино, 2009. С. 43–44.

3. *Болондинский В.К., Придача В.Б, Позднякова С.В., Виликайнен Л.М.* Исследование газообмена у листьев карельской березы и березы повислой в аномально жаркое лето 2010 г. // Тез. докл. Всерос. симп. «Растение и стресс». М., 2010. С. 66–67.

4. *Заленский О.В.* Эколого-физиологические аспекты изучения фотосинтеза. 37-е Тимирязевское чтение. Л.: Наука, 1977. 57 с.

5. *Лархер В.* Экология растений. М.: Мир, 1978. 382 с.

6. *Мокроносов А.Т.* Онтогенетический аспект фотосинтеза. М.: Наука, 1981. 196 с.

7. *Новицкая ЛЛ.* Карельская береза: механизмы роста и развития структурных аномалий. Петрозаводск, 2008. 143 с.

POSSIBLE ENVIRONMENTAL INFLUENCES ON THE FORMATION OF THE BIRDSEYE ABNORMALITY IN SUGAR MAPLE (ACER SACCHARUM MARSH.)

Bragg D.C.

USDA Forest Service, Southern Research Station, P.O. Box 3516 UAM, Monticello, Arkansas, 71656 USA, +01-870-367-3464,
dbragg@fs.fed.us

Abstract. Investigations on the birdseye grain abnormality in sugar maple (*Acer saccharum* Marsh.) have lately focused on possible associations with environmental conditions. One theory attributes its formation to elevated stand density, suggesting that increased competition for resources triggers birdseye production. This hypothesis has received only mixed support in related research. Recent microanatomical examination of birdseye sugar maple found localized aggregations of bark fibers press into the cambium, thereby damaging the cambial initials and, consequently, altering wood formation. No proximate cause for this phellogenetic origin was given, but elevated levels of the plant hormone ethylene acting upon the cork cambium were suspected. Birdseye formation differs from the physiological response seen in Karelian birch, and may result from xylem growth suppression due to poor nutrient supply following physiological changes in tissue structure. Both birdseye maple and Karelian birch are examples of environmentally triggered metabolic disorders with promise for silviculturally-based propagation.

The birdseye abnormality in sugar maple has puzzled lumbermen and foresters for centuries. The beautiful patterns of this figured grain have long been ornamentally prized—there are records of ancient Romans using figured maple in tables and other prized objects [2, 13]. In North America, early woodworkers often crafted birdseye maple into fine furniture, gunstocks, and other specialty items [12, 21], a tradition that has continued to this day (Figure 1). Currently, many of the best birdseye maple logs harvested from the United States and Canada sell for thousands of dollars *each* and are shipped overseas to Asian and European manufacturers (e.g., [10]). Unfortunately, even with the tremendous commercial interest that birdseye maple has been known to bring, there has not been any conclusive research on the cause(s) of this abnormality.

Figure 1. An example of birdseye maple wood in a finely crafted mantle clock. *Photograph by Bragg D. C.*

In recent years, investigations have focused on environmental conditions associated with birdseye sugar maple. A leading theory attributes its formation to elevated stand density, often measured in terms of basal area. A limited study of birdseye maples from the Upper Peninsula of Michigan (U.S.A) compared to nearby unfigured sugar maples of similar diameter and age found the birdseye specimens had local basal areas almost 25 % higher than their paired non-birdseye companions [14]. The authors of this study suggested that increased competition for resources led to elevated stress, which in turn triggered birdseye production. However, subsequent research on birdseye has not supported this competition hypothesis. Bragg et al. [7] expanded the comparison of birdseye versus non-birdseye maples to a much larger sample size over a broader geographic distribution. While the older, generally denser virgin stands of timber in their study had a higher proportion of birdseye maple than nearby managed second-growth, within strata birdseye maples were not found in areas of higher stand density [7].

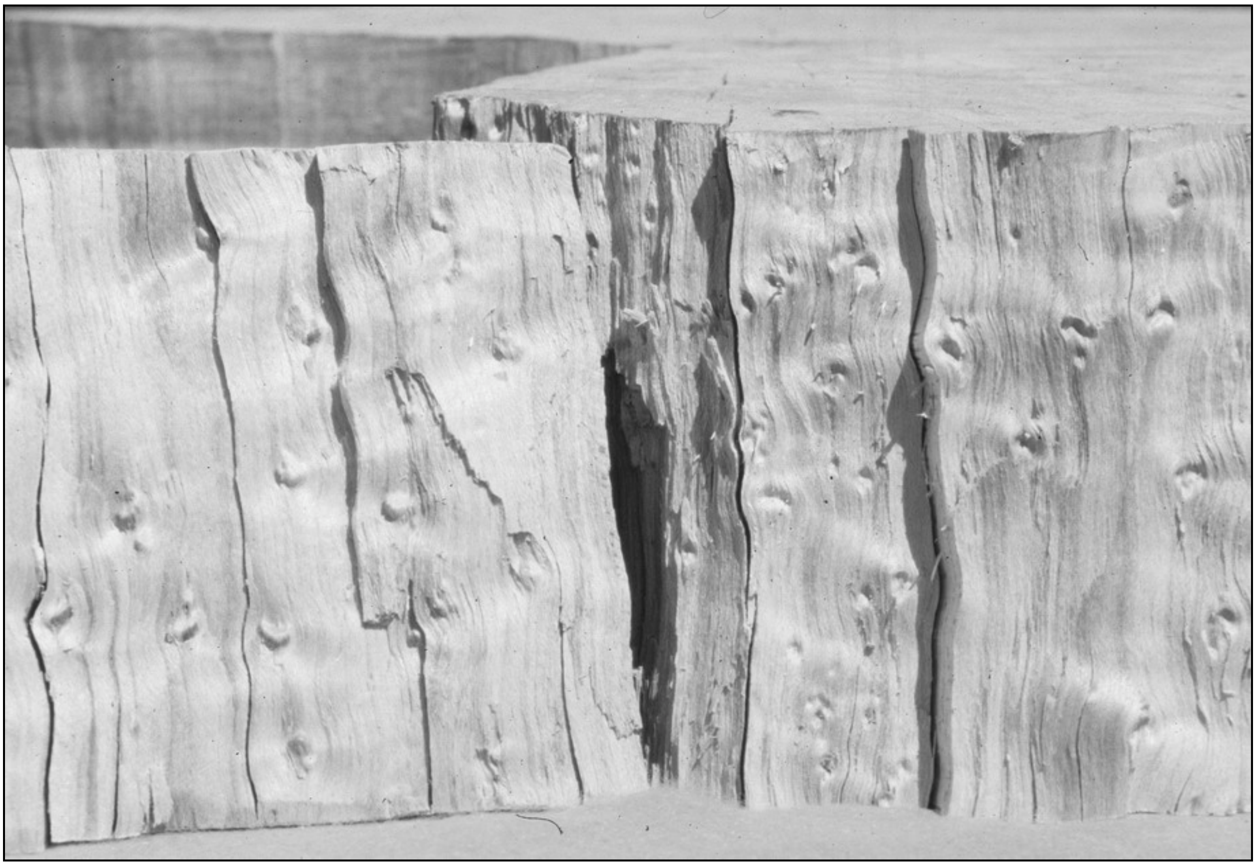

Figure 2. An example of the birdseye maple figured grain showing the localized impacts of bark fibers pressed against the developing cambial initials. *Photograph by Bragg D.C.*

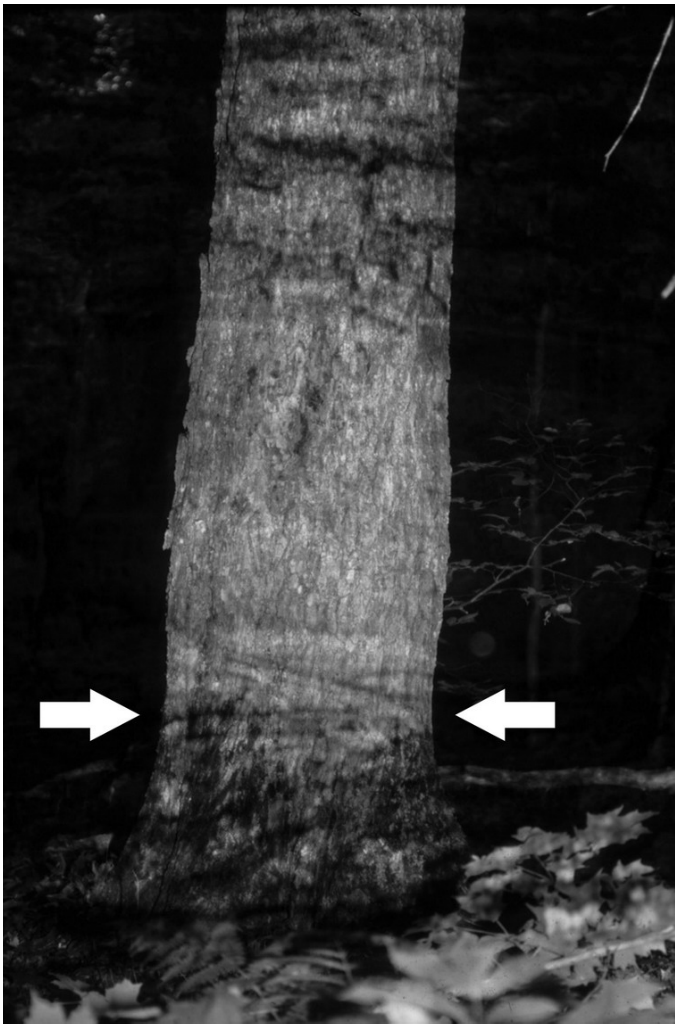

Figure 2. A large birdseye maple photographed in low light conditions to highlight the bole form. Note the constricted base of this tree (arrows), a feature often found with birdseye maples. *Photograph by Bragg D.C.*

Nevertheless, reports of the sudden termination of birdseye production following changes to stand conditions and the relative abundance of birdseye in old-growth stands still point to environmental link(s). Both Pillow [17] and Constantine [9] noted the abrupt cessation of birdseye following the harvesting of trees adjacent to birdseye maples. Presumably, the removal of these competitors changed the local environment enough to cause the birdseye maples to alter their physiology and cease the continuation of the figured grain. An additional anecdote mentioned a «perfect» log of birdseye maple sold to a mill in northern Michigan. Initially, this specimen produced highly figured veneer, only to abruptly cease less than 5 cm into the peeling of the log [21], indicating that the initiation of birdseye production can also be very rapid. The abundance of birdseye maple in many virgin northern hardwood forests [7, 10, 11, 21] and relative scarcity in managed second-growth [7] also point to environmentally controlled trigger(s) for birdseye production, perhaps mediated by time or ontogeny [4]. Additionally, a field guide to birdseye maple identification in standing timber suggested that birdseye was more abundant in certain locations on the landscape, including hills, upper portions of steep slopes, and locations with thin, dry, and/or rocky soils [8]. However, their phenomenological observation may simply be a consequence of fate—such locations may not have been logged due to access or tree quality issues and thus may better reflect the virgin forest condition, which often contains considerably more birdseye maple than managed stands [7].

Recent microscopic examination of birdseye sugar maple found localized aggregations of bark fibers pressing into the cambium, thereby damaging the cambial initials and, consequently, altering wood formation [18, 19, 20]. No proximate cause for this phellogenetic origin was given, but Rioux et al. [20] suspected that environmentally elevated levels of the plant hormone ethylene acting upon the cork cambium led to the formation of birdseye in sugar maple (Figure 2). The earlier cell differentiation and growth of the bark tissues may force the fibers against the inactive cambial initials, thereby producing a mechanical injury and subsequent physiological response [20]. Alterations to the size and abundance of rays may also affect nutrient transport to these tissues, producing localized areas of wood with decreased lignin in their cells [20]. Even though this injury may prove to be temporary, when it occurs over a multi-year period the reduced xylem growth produces a cumulative decline in radial increment for particular points along the bole and, hence, the characteristic indentations in the grain [4, 20]. The abrupt cessation of the figure further suggests that the influence of these bark fibers is not necessarily permanent and can be deactivated by the tree when conditions permit.

Evenn though both grain abnormalities arise from disturbances in cambial activity [4, 15, 20], birdseye formation differs in some ways from the physiological response seen in Karelian birch (*Betula pendula* var. *carelica* (Merckl.) Hämet-Ahti). Karelian birch develops following the sucrose-induced overgrowth of storage parenchyma cells [16]. Birdseye may result from xylem growth suppression due to poor nutrient supply following changes in tissue structure arising from the pressure of bark fiber concentrations [20]. Given that birdseye sugar maples can be found on what are considered good quality maple sites well within the natural distribution of the species [7], and has been documented to occur across the range of sugar maple [3], it seems unlikely that site-related macronutrient deficiencies directly lead to the production of birdseye, as found in Karelian birch [16].

Likewise, the occurrence of birdseye in numerous maple species, including a number of Eurasian and North American taxa other than *Acer saccharum*, implies that the physiological changes leading to birdseye production are also associated with conditions that are not limited to specific sites or even genotypes. However, the constricted «Coke-bottle» bole form often (but not always) observed in birdseye maples (Figure 3) is tantalizingly familiar to some of the abnormalities seen in Karelian birch [16] and perhaps suggests a structural limitation to the flow of water, nutrients, and/or photosynthates which may either trigger birdseye formation or reflect a physiological response to the processes involved.

Both birdseye maple and Karelian birch are examples of environmentally triggered metabolic disorders with promise for silviculturally-based propagation. Long-term experimentation has shown the efficacy of figured wood production in Karelian birch (e.g., [15, 16]) and a number of other figured grains (e.g., [1]). No such comparable experiments have been published for birdseye maple, indicating we have much work left to do on the developmental pathways of this grain abnormality. Silvicultural advice to help ensure the continued availability of birdseye maple has been slow in coming (e.g., [5, 6]) but should increase as the relationship between the formation of this figured grain and environmental influences becomes better defined.

LITERATURE

1. *Beals, H.O. and T.C. Davis.* Figure in wood: an illustrated review. Auburn Agricultural Experiment Station, Auburn University, Auburn, AL, USA. 1977. 79 p.
2. *Boulger, G.S.* Wood. Edward Arnold Publishers, London, UK. 1902.
3. Bragg, *D.C.* Birdseye sugar maple's geographic range and some implications for management // Northern Journal of Applied Forestry. 1995. 12. P. 86–89.
4. *Bragg, D.C.* The birdseye figured grain in sugar maple (*Acer saccharum*): literature review, nomenclature, and structural characteristics // Canadian Journal of Forest Research. 1999. 29. P.1637–1648.
5. *Bragg, D.C.* Potential contributions of figured wood to the practice of sustainable forestry // Journal of Sustainable Forestry. 2006. 23(3). P. 67–81.
6. *Bragg, D.C.* Preliminary silvicultural recommendations and an updated annotated bibliography for birdseye sugar maple // In Jacobs, D.F. and C.H. Michler, eds. Proceedings, 16th Central Hardwoods Forest Conference. USDA Forest Service General Technical Report NRS-P-24. 2008. P. 114–129
7. *Bragg, D.C., G.D. Mroz, D.D. Reed, S.G. Shetron, and D.D. Stokke.* Relationship between «birdseye» sugar maple (*Acer saccharum*) occurrence and its environment // Canadian Journal of Forest Research. 1997. 27. P.1182–1191.
8. Centre d'enseignement et de recherche en foresterie de Sainte-Foy (CERFO). Field guide for identifying birdseye maple. CERFO, Sainte-Foy, Quebec, Canada. 1996. 29 p.
9. *Constantine, A.* Know your woods. Home Craftsman Publishing Corporation, New York, NY, USA. 1959.
10. *Gagnon, J.* Hard maple, hard work. Northern Michigan University Press, Marquette, MI. 1996. 232 p.
11. *Hough, F.B.* Report on the forest condition and lumber and wood trade of New Hampshire and West Virginia // In Egleston, N.H. Report on forestry, volume IV—1884. US Government Printing Office, Washington, DC, USA. 1884. P. 348–387.
12. *McCabe, C.* Figured woods // Early American Life. 2003. 34(2). P.50–55.
13. *Meiggs, R.* Trees and timber in the ancient Mediterranean world. Clarendon Press, Oxford, UK. 1982. 553 p.
14. *Mroz, G.D., D.D. Reed, and W.E. Frayer.* An evaluation of bole form and microsite conditions for birdseye maple growing in the western Upper Peninsula of Michigan // Northern Journal of Applied Forestry. 1990. 7(1). P. 44–45.
15. *Novitskaya, L.L.* Regeneration of bark and formation of abnormal birch wood // Trees: Structure and Function. 1998. 13. P. 74–79.
16. *Novitskaya, L.L.* Karelian birch: mechanisms of growth and development of structural abnormalities. Petrozavodsk, Russia. 2008. 143 p.
17. *Pillow, M.Y.* «Bird's eyes» in maple are not due to dormant buds // Hardwood Record. 1930. 68. P. 45–46.
18. *Rioux, D.* Birdseye maple: a matter of hormones? Branching Out [newsletter of the Laurentian Forestry Centre of the Canadian Forest Service], 2006. Issue 30. 2 p.
19. *Rioux, D., T. Yamada, M. Simard, G. Lessard, F.J. Rheault, and D. Blouin.* Anatomy and cytochemistry of birdseye sugar maple [abstract] // Canadian Journal of Plant Pathology. 1999. 21. P. 204–205.

20. *Rioux, D., T. Yamada, M. Simard, G. Lessard, F.J. Rheault, and D. Blouin.* Contribution to the fine anatomy and histochemistry of birdseye sugar maple // Canadian Journal of Forest Research. 2003. 33. P. 946–958.

21. *Sherwood, M.H.* From forest to furniture: the romance of wood. W.W. Norton & Company, Inc., New York, NY, USA. 1936. 284 p.

PLANT GROWTH REGULATORS CIRCON AFFECTS PLANT RESPONSES TO ENVIRONMENTAL FACTORS

Budykina N.P., Titov A.F.

Institution Russian Academy of Sciences Institute of Biology Karelian Scientific Center. E-mail: timeiko@krc.karelia.ru

Abstract. The effect a new plant growth regulator on the natural mineral circon on potato and cauliflower plants was studied under the climatic conditions of Karelia. It was shown that the preparation stimulated the growth and development of plants and increased their productivity under low temperatures and deficit and excess water stresses: it manifested antistress and fungicidal activities.

МОДИФИКАЦИЯ РЕАКЦИИ РАСТЕНИЙ НА ДЕЙСТВИЕ НЕБЛАГОПРИЯТНЫХ ФАКТОРОВ ВНЕШНЕЙ СРЕДЫ С ПОМОЩЬЮ СИНТЕТИЧЕСКОГО РЕГУЛЯТОРА РОСТА ─ ЦИРКОНА

Будыкина Н.П., Титов А.Ф.

Учреждение Российской Академии наук Институт биологии Карельского научного центра РАН, г. Петрозаводск, Россия.
Тел(8142)762712. E-mail: timeiko@krc.karelia.ru

Интенсификация растениеводства в северных регионах нашей страны предполагает регулирование процессов роста и развития растений, а также улучшение их адаптивных возможностей с целью обеспечения стабильных урожаев при неблагоприятных условиях внешней среды. К настоящему времени накоплен значительный объем данных о повышении устойчивости растений с помощью синтетических аналогов фитогормонов, а также соединений не гормональной природы [3, 6, 14–16, 18]. В последние годы к вновь синтезируемым препаратам добавилось требование повышения уровня их экологической безопасности и необходимость разработки энергосберегающих технологий их производства и применения. Исходя из этих требований, уже получен ряд новых синтетических регуляторов на природной основе [13, 17], – безвредных, экологически безопасных и высокоэффективных при низких нормах их расхода (5 – 50 мг/га). Один из них ─ препарат циркон [11], зарегистрирован Госхимкомиссией и внесен в Государственный каталог пестицидов и агрохимикатов, разрешенных к применению на территории РФ. Его действующим веществом является смесь природных гидроксикоричных кислот (ГКК) и их производных, выделенных из лекарственного растения эхинацеи пурпурной (*Echinacea purpurea* (L.) Moench.).

Биологическая активность циркона в значительной степени обусловлена антиоксидантными свойствами, характерными для фенольных соединений [9]. Согласно литературным данным [2, 4, 5, 12, 19], циркон активизирует процессы синтеза хлорофилла, рост и ризогенез растений, компенсирует дефицит природных регуляторов роста, повышает устойчивость растений к биотическим и абиотическим факторам среды, выполняет функции индуктора цветения растений. Однако, несмотря на выявление этих важных свойств у препарата, требуются более детальные исследования его действия на растения в конкретных почвенно-климатических условиях.

Исходя из этого, целью наших исследований являлось изучение возможности модификации с помощью циркона реакции растений на действие неблагоприятных факторов внешней среды, характерных для условий Карелии.

Исследования проводили на картофеле (сорт Петербургский) и на цветной капусте МОВИР - 74 на Агробиологической станции Института биологии Карельского научного центра РАН (расположенной в пригороде г. Петрозаводска), путем постановки мелкоделяночных опытов.