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A UNIQUE MODE OF THE NATURAL PROPAGATION OF *GINKGO BILOBA* L. – THE KEY TO THE PROBLEM OF ITS "SURVIVAL"

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ABSTRACT. The paper presents the description of the exogenous adventive aerial roots (such roots are known under the japanese name chichi) in one of the two female trees of *Ginkgo biloba* L. in the Botanical Garden of the Jagiellonian University in Kraków. These roots are determined in their growth and produce the vegetative branches through the formation of the callus buds. The vegetative propagation of *Ginkgo* by these vegetative buds at aerial roots has been observed in the favourable environments in Japan and China (Harrison & Dallimore 1966, Tredici 1992). The unique for a tree mode of the vegetative propagation in the combination with cotyledonary buds regeneration (Tredici 1992) has promoted the distribution of *Ginkgo* in the past floras and its "survival".

KEY WORDS: *Ginkgo biloba*, aerial roots

One of the two female trees of *Ginkgo biloba* L. (Fig. 1) in the Botanical Garden of the Jagiellonian University in Kraków attracted my attention in 1989 because of its aerial adventive roots without and with choot buds at the top of some of these roots. But I managed to produce adequate photographs only in December 1992[1].

I have treated my observation as a palaeobotanist mystified by the problem of "a survival" of the plant characterized by the combination of the incompatible with a neobotanist's point of view features such as woody habit and a number of features including the pollen chamber and motile spermia that is typical of ferns and cycads. The analogues contradictory combination of a woody habit with the fern type reproductive biology typical of archaeopterids appeared tragic in their fate – they could not win the competition with woody gymnosperms. The advantage of the last was in the development of a seed.

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[1] Many small round aerial roots was firstly observed in December, 1994 in one of the oldest masculine trees of *Ginkgo biloba* (in the Botanical Garden of the Jagiellonian University). They were absent in December 1992. It is possible to suggest that they are two years old. The further observation are desirable.

Fig. 1. The female tree of *Ginkgo biloba* L. with roots in the Botanical Garden of the Jagiellonian University in Kraków

Aerial roots in *Ginkgo* are well known for dendrologists. But such roots are not mentioned in most of text-books and popular manuals on botany and palaeobotany. Books "Im Lande der angehenden Sonne" by H. Molisch (1926) and "Plant life through the ages" by A. C. Seward (1933) are probably the exceptions. Both had published the same photo of the old trunk of *Ginkgo* from Japan with big stalactite like aerial roots descending around a thick main trunk. Many aerial roots in *Ginkgo* long plagiotropic lateral shoot have been also observed in Japan (Takami 1955). Aerial roots in *Ginkgo* (not necessary in old trees only) were registered in botanical gardens of Europe, e.g. in Warsaw in Poland (Kobendza 1957) and in Görlitz in Germany (Von Kameyer 1957–1958) (Fig. 2). Kobendza (1957, p. 46) noted: "Na pniu najstarszego milorzębu w warszawskim Ogrodzie Botanicznym dają się zauważyć zaczątki narośli typu chi-chi. Jeśli się okaże, że one rosną, to będzie to jedyny w Polsce egzemplarz, na którym pojawiły się narośla tego typu". Thus it is possible to suggest that as early as 1957 aerial roots in Kraków female specimen had not yet been formed[2]. It is very unlikely that such an eminent expert in *Ginkgo* as Kobendza could overlook aerial roots at the plant in Kraków.

The aerial roots hanging down in the lower part of the Kraków female tree of *G. bi-*

[2] A short information on the chi-chi in the Kraków *Ginkgo* was published by W. Seneta (1981) in his book ("Drzewa i krzewy iglaste". PWN, Warszawa on 198 p.). Unfortunately I have received this citation from D. Zdebska after I have presented my paper for publication.

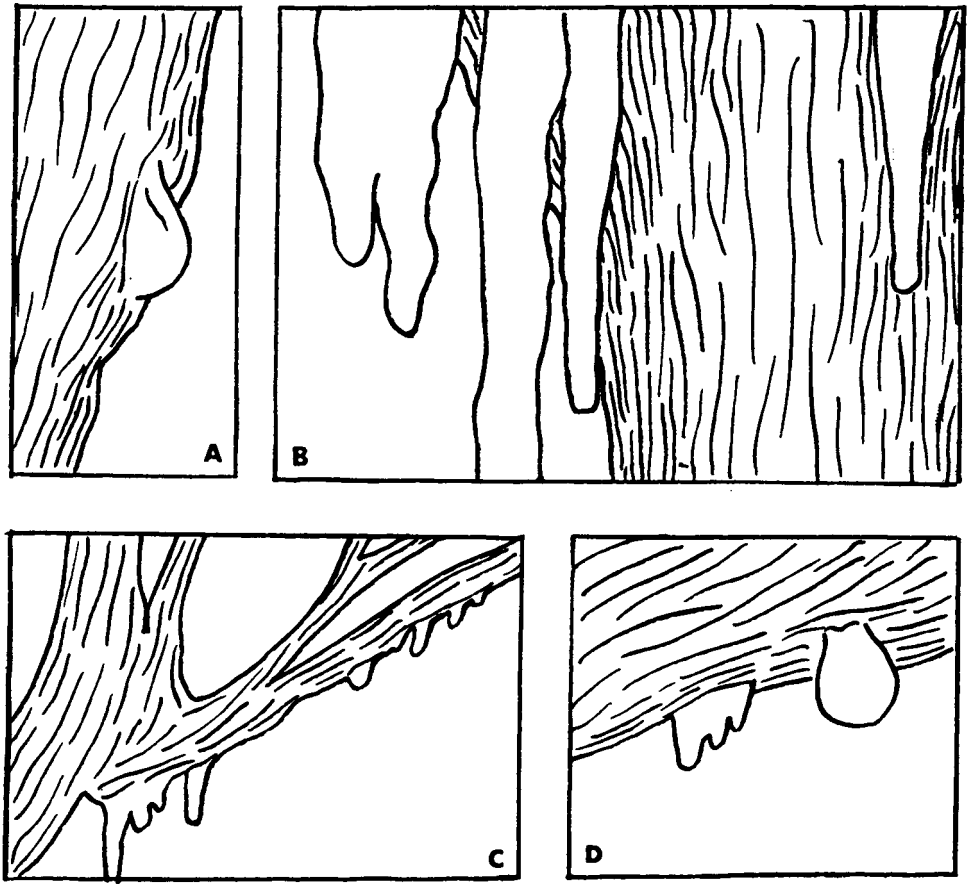

Fig. 2. Schematic drawing illustrated different shape of aerial roots in *Ginkgo biloba* L. A – the young root in tree, Warsaw Botanical Garden (Kobendza 1957), B – very long (up to 5 m) aerial roots at the old main trunk (Molisch 1927, Seward 1933 – the same trunk), C – aerial roots at the lateral branch in Japan (Takami 1955), D – young roots in the lateral branch in Görlitz (Von Kammeyer 1957–1958)

loba can be seen at Pl. 1 figs 1–2. These roots are similar to young stilted roots of mangrove plants in the early stage of the roots development. Roots in *Ginkgo* are cylindrical, become narrower at the top, up to 0.5 m long. The cortex is cracked as a result of the active growth of organs.

As shown in the Pl. 1 fig. 1, and Fig. 3, the successive phases of the root formation are observed in the place where the callus is actively formed. Such mode of the root formation in the association with the callus was described by Fujii in 1895 and lately observed by Tredici (1992). There is a similarity of some roots at the first stage of their development to the flowage forms of the callus produced by the metal railings in many gymnosperms and angiosperms.

The stable morphology of these organs showed that their shape and growth are connected with the activity of the apical meristem. The foundation of the latter appeared to

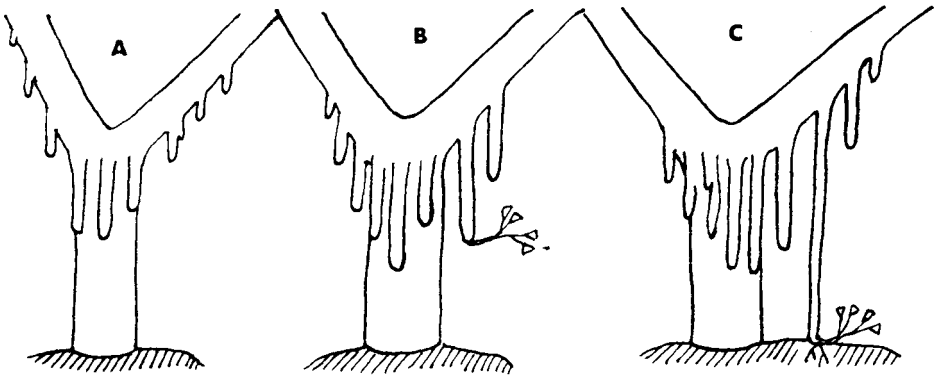

Fig. 3. Schematic drawing of different stages in the ontogenesis of the aerial roots in *Ginkgo biloba* L. A. – early stages with or without (?) yet shoot buds, B – one on the roots was determined in the growth and has produced the leafy brunch in the distance from the ground; C – one of the roots has reached the ground and the produced leafy brunch has taken root

take place in a callus, as evidenced by the Kraków tree (Pl. 1 fig. 1). The formation of the cauline exogenous adventive roots in the woody plants is known to occur in a callus or in the secondary phloem, or on the phellogene of the secondary cortex (Voronin 1964, Esau 1969). Parenchyme cells are differentiated into vascular system elements and so the connection of young root with the mother organ is provided (Esau 1969). Aerial roots of the Kraków tree have not yet been studied anatomicaly. The question of the origin and of the ontogenesis of the aerial roots is worthy of the special study.

The formation of the exogenous adventive roots of the callus nature in *Ginkgo* is very well known to occur in the culture of the artificial vegetative propagation of plants by cuttings (Kobendza 1957) and by leaves (Baranova 1949). The observation by Baranova (1949) in the Main Botanical Garden in Moscow showed that the root formation in leaf petioles took place only without the treatment by heteroauxine. The root formation occurred in a zone originated in a callus cambium. The annual alteration was observed in the formation of roots and buds in different years.

The callus formation in leaf petioles took place in ancient ginkgophytes too. For example, it is possible to observe some callus roots in one of the samples of *Rhipidopsis densinervis* Feistm. in text-fig. 11 and plate 4, fig. 2 from the Permian Gondwana of the Rajmahal Basin described by Maheshwari and Bajpai (1992). Many years ago I observed similar roots in specimens of ginkgophytes from the Russian Jurassic in collections by A. I. Turutanova-Ketova. Unfortunately that time I could not properly interpret the unusual position of roots in the organic connection with leaf petioles.

Since the aerial root formation in *Ginkgo* tree is related with shoot buds development it is very essential for the natural propagation biology of plants. One of the aerial roots (Pl. 1 fig. 2 to the right) of the Kraków tree has stopped growing and is replaced by the vegetative branch attracted by the ground surface. It appears to be the result of the prolonged hormonal influence of the root preadaptated to the positive geotropism. It is possible that three roots placed nearby (Pl. 1 fig. 2, to the left) also will be transformed

into the vegetative shoot through the formation of the callus buds. A special observation is needed to answer the question.

The succession of a structure and a function of the vegetative organs in the Kraków female tree of *Ginkgo* through some kind of super structuring and overtopping of the determined in the growth adventive roots by the vegetative branches, appear to be connected with the ecology and with the specific behaviour of the plant in connection with a graviperception. In the favourable environments an ability of *Ginkgo* to the vegetative propagation by rooting of branches formed at the aerial adventive roots is reported by some researchers. For example, Harrison and Dallimore (1966 p. 231) noted: "Trunks and branches of old trees developing burry, peg-like structures which grow downwards and on reaching the ground develop true roots from the apex and produce leafy branches above". Therefore the vegetative propagation observed in *Ginkgo* is very unusual for a true tree in the extant flora.

It would be very important to study the physiological mechanism of the determination of the aerial root growth in different environments. The determination of the root growth in Kraków tree prevents to realize the unique ability of *Ginkgo* to the natural vegetative propagation potentially characteristic of the ancient plant. It also seemed a very important biological peculiarity in the native habitat. It would be interesting to observe in the Kraków Botanical Garden whether aerial roots without buds could be implanted producing the leafy branches after they are put on the ground indoors and out of doors in the experiment. But it is possible to suggest that some kind of the internal biological clock could indicate their unreadiness to the vegetative propagation. On the contrary, a contact with a ground might be a signal for taking root and the bud formation observed in some aerial roots out of touch with the soil.

Then a question arises whether the exogenous adventive aerial roots with the exogenous buds formation in the tree stem in *Ginkgo* had indeed the evolutionary importance. Although the callus formation very often occurs in conifers and angiosperms trees the natural vegetative propagation of *Ginkgo* by implanting of the aerial roots with vegetative buds is unique. Such kind of the propagation could be characteristic of the ancient representatives of the genus *Ginkgo* whose history counts about 200 mln years, if we accept its origin in the early Jurassic. In this case the feature known in the only extant species of the genus could be interpreted as archaic and losing its biological meaning during the evolutionary aging of the genus. *Ginkgo* is well reproduced by seeds. Meanwhile there is an opinion that a parthenogenesis is characteristic of *Ginkgo*. Some researchers (e.g. Harrison & Dallimore 1966) are in doubt about it. But Lypa (1966) had supported a view of a parthenogenesis in *Ginkgo*. He observed the abundant germination of seeds under the female trees isolated from male ones in Sukhumi and Tchakvi in the Transcaucasia.

The aerial roots of *Ginkgo* might be some kind of relic stilted roots developed in the ancient representatives of the genus adapted to the mangrove habitats, not necessary connected with a sea: the fresh water mangroves are also known. The stilted root formation could be lost in other environments where the only extant species *G. biloba* was originated. But the ability to the partial realization of the internal potency of plants to

the root formation could be yet preserved and adventive roots acquired the new importance for the vegetative propagation.

Finally, it is possible that the natural vegetative propagation by the callus aerial roots with shoot buds was in fact unrelated with stilted roots of mangrove plants and has been originally characteristic of ginkgophytes as a group. In this case this unusual kind of the vegetative propagation observed in *Ginkgo* could be the evolutionary innovation into ginkgophytes through the long history of seed plants. In any case in the combination with the parthenogenesis and lately described the regeneration through the cotyledonary chichi with vegetative buds (Tredici 1992) it promoted the distribution in floras of the geological past and finally the "survival" of *Ginkgo*.

The new observation on the downward growing cotyledonary buds in *G. biloba* published by Tredici (1992) are very important too for natural propagation of plants. As the author noted (Tredici 1992, pp. 529, 530): "cotyledonary buds... can form a downward growing basal chichi in which growth is limited to the proliferation of physiologically suppressed shoot buds – this happens following particularly severe injury to either the root system or the lower part of the shoot system.... The phenomenon of clonal regeneration from basal chichi has not only contributed to the long-term persistence of *Ginkgo biloba* in forests of China, but may also have played a role in the survival and morphological stability of the genus since the Cretaceous".

The formation of the regenerative buds in *Ginkgo* not only in the tree crone as typical of phanerophytes but also in specific organs-aerial cauline roots and in underground cotyledonary rhizom-like organs (Tredici 1992) was very important advantage in the natural propagation strategy of the woody plant. This advantage has played the compensatory role taking into account the imperfect reproductive sphere of *Ginkgo* typical of herbaceous and arborescent ferns and cycads. The innovation in the biology of the plant and the group ginkgophytes as a whole, connected with different modes of the natural vegetative propagation and of the protection of the regenerative buds has promoted *Ginkgo* to outlive its Mesozoic coevals in the competition with woody conifers and angiosperms. *Ginkgo's* life form passes the limits of the traditional classification and combines three modes of the protection of the regeneration buds characteristic both of phanerophytes and geophytes.

The adventive cauline roots in *Ginkgo* again remind on the relationships of the genus with seed ferns. Takhtajan (1978) has suggested the common seed fern precursor for *Ginkgopsida* and *Pinopsida*. Meyen (1981, 1982) argued that *Ginkgo* is the true seed fern in the extant flora. The idea has impressed me.

In connection with the different modes of the natural propagation of *Ginkgo* the "abnormal" kind of the generative reproduction is worthy to be reminded. Sometimes the normal seeds formation in *G. biloba* take place at leaf lamina (Mijoshi 1931, Bierhorst 1971), which looks like a pteridosperm fructification. Mijoshi (1931, p. 22) evidenced: "Der Ginkgobaum, auf dessen Blätter Fruchtbildung stattfindet, ist in neurer Zeit in einigen Örtlichkeiten wiederholt gefunden worden. Doch repräsentiert der oben erwähnte Baum das bekannteste und zugleich älteste Exemplar dieser genetisch höchst interessanten Monstrosität. Auf eine derartigen Ginkgobaum werden die anomalen Früch-

te gewöhnlich in viel geringerer Anzahl gebildet als die normalen". Bierhorst (1971, p. 421) wrote: "Ovules are occasionally born on vegetative leaves, and sometimes the normally ovule bearing organ is in part laminate. The lamina in such cases is derived by tissue proliferation at or below the base of the ovule". Some seeds on the leaf lamina appear to be of the callus nature too and demonstrate another unique potency of *Ginkgo* in the female reproductive structure formation from the somatic cells. This question is worthy too to be the subject of special studies.

The great abundance of papers on different of morphology, anatomy, cytology, embriology including for example callus formation by ambryo in vitro (Webb et al. 1986), physiology, ecology etc. of *Ginkgo* has been published. The author's tasks are to attract-attention of palaeobotanists to aerial roots in *Ginkgo* and unusual for trees the mode of the natural vegetative regeneration which is so characteristic of the ancient plant. It would be very important to collect data on the exogenous callus roots at leaf petioles and on seeds at the leaf lamina in fossil ginkgophytes.

My observations of chichi in *Ginkgo* have excited me so strongly that I could not but share them with my collegues – palaeobotanists who have not been acquainted with the mistery organs characteristic of the alive fossil.

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PLATES

Plate 1

1. The successive stages of the callus aerial roots formation in *Ginkgo biloba* L. Botanical Garden, Jegiellonian University, Kraków
2. There are aerial roots. The vegetative leafy shoot is growing to the right. Botanical Garden, Jagiellonian University, Kraków

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