ACTA SOCIETATIS
BOTANICORUM POLONIAE
Vol. 56, nr 1: 147–154
1987

Anatomical-morphological changes in *Glyceria aquatica* (L.) Wahlb. and *Phalaris arundinacea L.* growing in the zone inundated by the Kwiecko lake

EUGENIUSZ R. ŚPIEWAKOWSKI, MARIA WIELICKA, JÓZEF PIASECKI

Department of Botany and Ecology, Technological-Agricultural University, Bernardyńska 6, 85–029 Bydgoszcz, Poland

(Received: December 27, 1985. Revision accepted: April 4, 1986)

Abstract

Morphological-anatomical changes are described in the shoots of *Glyceria aquatica* and *Phalaris arundinacea*. These grasses encroach upon the zone inundated by the lake Kwiecko which is the lower reservoir of the Hydroelectric Plant Żydowo. The interaction of habitat and anthropogenic factors causes disturbances in the physiology of reproduction in the above mentioned plants and produces changes in their external and internal structure. Both species form in the zone inundated by the lake vegetative shoots exclusively, with profuse aerial tillering at the apical meristems. The morphological changes consist in shortening of the shoots and multiplication of the internodes. In the internal structure a narrowing of the ring of sclerenchyma, a shift of the vascular bundles into the sclerenchyma and an increase of its layer and air channels are observed.

Key words: *morphology*, *anatomy*, *Glyceria aquatica*, *Phalaris arundinacea*, *habitat*

INTRODUCTION

During operation of the hydroelectric plant at Żydowo (District Koszalin) there arise around the lakes Kamienno (retention reservoir) and Kwiecko (lower reservoir) zones of incoming tide and ebb-tide of the energetically effective waters comprising 2/3 of the storage volume of these reservoirs. At maximal water levels and draining of the lakes the 24-h water level oscillations amount from 3.1 to 3.5 m. These variations produce during transgression and regression of the waters the formation of zones similar to the shores of seas and oceans.

The flood-and-ebb-zone of the Kwiecko lake which is the object of interest in the present investigations occupies a surface of 64 ha, mostly

deprived of vegetation cover. Along the line of the higher part of the littoral zone rather strong processes of erosion and abrasion are noted, causing shallowing of the lake basin. The substrate of the inundation zone is not stable, sodden and silty.

The lack of a solid substrate and the necessity for the plants of living in two ecological environments — an aquatic one when the lake is filled and a land (air) one — during outflow constitutes the basic barrier for settling in the tide zone of a greater number of vascular plants.

The aim of the study was investigation of the morphological-anatomical adaptation of *Glyceria aquatica* and *Phalaris arundinacea* to wide variations of the water level in the Kwiecko lake. Morphological studies concerned the length of inflorescence, and of internodes and width of some leaves, while anatomical examination dealt with the distribution of the sclerenchyma layer of the vascular bundles, the aerenchyma and air ducts.

MATERIAL AND METHODS

The plant material for morphological-anatomical studies was taken from the flood-plain forest and the inundated zone of the postglacial lake Kwiecko with a surface area of 88 ha, serving as lower reservoir for the hydroelectric plant in Żydowo.

This area is occupied by few plant species among which *Glyceria*

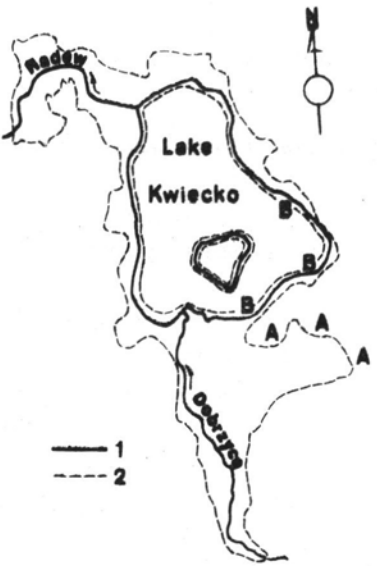

Fig. 1. Plan of distribution of sites: A — flood-plain forest, B — inundation zone, 1 — natural lake shore, 2 — maximal and minimal limit of inundation

Table 1

Mean results of biometric and anatomical measurements of shoots of *Glyceria aquatica* (L.) Wahlb. and *Phalaris arundinacea* L.

Examined feature	Unit	*Glyceria aquatica*		*Phalaris arundinacea*	
		habitat		habitat	
		flood-plain forest	inundation zone	flood-plain forest	inundation zone
Length of inflorescence	cm	24.1	–	12.5	–
Length of shoot	cm	141.2	63.2	144.4	50.0
Number of internodes	piece	7.0	16.2	6.6	10.0
Length of internodes	cm	19.1	3.9	21.5	5.0
Length					
— of first internode	cm	43.2	1.2	33.7	1.8
— of last internode	cm	10.4	3.9	7.0	7.0
Width of second leaf	mm	10.0	10.0	12.0	9.0
Aerial tillering	%	3	7	abundant	very abundant
Number of sclerenchyma layers	piece	7	2	4	3
Thickness of sclerenchyma	μm	110	22	60	40
Surface area of aerial channels.	μm	–	aerenchyma	–	220/130

aquatica (L.) Wahlb. and *Phalaris arundinacea* L. are frequently found. In 1985 100 specimens of each of these species were collected at the points marked on a sketch of the terrain (Fig. 1). The plants differed distinctly in habitus. For comparison biometric measurements were performed of the inflorescence length, number and length of all internodes, width of the blade of the second leaf from above on the shoot (Table 1).

For anatomical examination 3-cm segments were taken from the internodes of the rhizomes and shoots. After dehydration of the plant material in 70 per cent ethyl alcohol solution sections 90 μm thick were cut with a sliding microtome. The preparations were fixed in an ethyl alcohol-glycerin mixture (1:1). The prepared cross sections served for analysis of the internal structure as illustrated by the microphotographs (Figs. 4A, B and 5A, B).

RESULTS

GLYCERIA AQUATICA (L.) WAHLB. (FIG. 2)

Generative shoots of *Glyceria aquatica* from the flood-plain are erect of 141.2 cm mean length. The haulms are divided on the average into 7 internodes. The latter are longest under the inflorescences (mean 43 cm),

and their length decreases with the distance from it. The mean length of the lower internodes is 10.4 cm. It was noted that sporadically, about in 3 per cent of the examined shoots, lateral branchings grow out of intercalary meristems. The mean width of the blade of the second leaf from above on the shoot is 10 mm. The inflorescence — a true panicle — has a mean length of 24.1 cm.

Under the epidermis there is a rather regular 4–5-layer, 56 μm thick ring of sclerenchyma and in it small collateral vascular bundles are sporadically dispersed. The haulm of *Glyceria aquatica* is additionally strengthened by a second three-layer ring of sclerenchyma which forms a bridge between the large vascular layer situated within the parenchyma. In the centre of the haulm there is a pith channel.

Glyceria aquatica penetrates into the inundated zone of the lake which is not typical for this species. It forms here vegetative trailing shoots exclusively, resembling stolons (Fig. 3). These shoots consist on the average of 16.2 internodes of 3.9 cm mean length. The internodes are longest at the base and shorter towards the apex measuring 1–2 cm. White adventitious roots and leaves grow from the intercalary meristems, which soon die in the lower and central nodes owing to the undulation of the water. Side branchings of higher internodes form seven per cent of the examined shoots. The mean width of the second leaf blade from above on the shoot is 10 mm (Table 1).

In the tissue arrangement a two-layer 22 μm thick ring of sclerenchyma was observed with large cell lumens under the epidermis. The vascular bundles are distributed in whorls at the pith channel. The remaining parts of the cross section are filled with a network of sclerenchyma cells.

The anatomical structure of *Glyceria aquatica* rhizomes from the flood-plain forest and zone inundated by the lake Kwiecko is similar and exhibits the following characteristic pattern of tissues: epidermis, a one-layer ring of sclerenchyma cells, sclerenchyma and in it vascular bundles arranged close to the pith channel.

PHALARIS ARUNDINACEA L. (FIG. 4)

The generative shoots of *Phalaris arundinacea* from the flood-plain forest are erect of a mean length of 144.4 cm. The haulm is divided into 5–7 internodes. Those under the inflorescence are on the average 33.7 cm long, their length decreasing towards the base. The mean length of the lower internodes is 7.0 cm. At various levels of the haulm single rather numerous lateral branchings grow from the intercalary meristems. The width of the second leaf blade from above on the shoot is 12 mm. The haulm ends in a true panicle of 12.5 cm length.

In the anatomical structure of the haulm there appears under the epidermis a ring of sclerenchyma consisting of four layers of cells. Small vascular bundles are dispersed in it, separating islands of assimilative parenchyma. Within the parenchyma lies a second ring of large vascular bundles in a whorl. The centre of the cross section is occupied by the pith channel.

Phalaris arundinacea also penetrates into the zone inundated by the lake, untypical for this species. These sites are overgrown by a form with erect but exclusively vegetative shoots. The shoots are divided into numerous internodes (10) of mean length 5.0 cm. The longest internodes are found at the base and become shorter towards the apex. The characteristic for *Phalaris arundinacea* ability of tillering in the air is very pronounced under the conditions of the inundation zone of the lake Kwiecko. This grass in the apical part of the shoot forms manylevelled branchings, assuming a "broom-like" form (Fig. 5). The blade width of the second leaf from above on the shoot is on the average 9 mm (Table 1).

In the internal structure of the shoot, under the epidermis there is a several-layered ring of sclerenchyma and within it dispersed small vascular bundles. The cells of assimilative parenchyma have been torn giving rise to air channels stretched along the shoot circumference. Their mean surface area is 220/130 μm each. There are 18 of them on the cross section. The remaining parts of the cross section are filled with parenchyma with a second whorl of large vascular bundles. In the centre of the cross section lies a large pith channel.

The arrangement of tissues in the rhizomes of *Phalaris arundinacea* from the flood-plain forest and zone of inundation by the lake Kwiecko is as follows: epidermis, multilayered parenchyma, ring of endodermal cells, sclerenchyma and within it nonuniformly distributed vascular bundles. In the parenchyma of *Phalaris arundinacea* plants from the inundation zone large air channels have formed with surface area of 550/150 μm each, stretching around the rhizome circumference.

DISCUSSION

The extremal changes of ecological conditions in the zone inundated by the Kwiecko lake are connected with the work of the hydroelectric plant. They evoke a number of modifications in the morphological-anatomical structure of *Glyceria aquatica* and *Phalaris arundinacea* shoots. The cyclic and violent variations of the water level in the water body cause movement of the bottom sediments, disturb thermic stratification and productiveness of hydrophytes (Śpiewakowski 1974, 1977, 1979, Korzeniewski and Śpiewakowski 1977a, b).

The whole group of ecological factors exerts a direct influence on the physiology of reproduction of the plants in question. Inundation of these grasses and shading of the aquatic biotope deprives them of access to light and makes transition from vegetative to generative phase impossible. On account of oscillation of the water level in the lake, the grasses lose most leaves on the shoots. Our observations are confirmed by the studies of Strebeyko (1971) and Śpiewakowski et al. (1985a).

Apical tillering on vegetative shoots standing out above the water level, especially in *Phalaris arundinacea* depends distinctly on the intensity of photosynthesis processes. The shoots of these plants in the inundation zone are shorter with very numerous shortened internodes. Similar results and observations of meadow grasses may be found in the paper by Minderhoud (1978) and Olszewska and Wielicka (1981, 1984).

The internal structure of tissues in shoots of the studied plants indicates their adaptation to drastic changes in the water level of the lake. Restriction of the contribution of parenchyma and the shift of the vascular bundles in the vegetative shoots of *Glyceria aquatica* deeper into the parenchyma increases the elasticity of the shoot and protects it from mechanical injury during undulation of the surface water layers (Śpiewakowski et al. 1985b). The increase in the aerenchyma and air channels volume facilitates gas diffusion in immersed plants.

Particularly noteworthy is the fact that each of the studied plant species of the inundation zone of the lake has produced a different anatomical adaptation. This is evidence that the reaction of plants to a definite group of habitat factors occurs not only within a family, but also in lower syntaxonomic units such as for instance species and variety. It results from field observations and laboratory studies that both species of grasses ensure to a high extent stabilisation of the substrate of the inundation zone, owing to greatly developed stolons. These grasses have relatively large regeneration possibilities and a very elastic tissue structure. All these features indicate that they may be used in biological engineering in the inundated zone deprived of vegetation.

REFERENCES

Korzeniewski K., Śpiewakowski E. R., 1977a. Hydrochemical study of Kamienno and Kwiecko lakes. Part I. Data from the 1967–1969 investigations (before the building of the power station at Żydowo). Pol. Arch. Hydrobiol. 24: 137–145.

Korzeniewski K., Śpiewakowski E. R., 1977b. Hydrochemical study of Kamienno and Kwiecko lakes. Part II. Data of 1971–1972 (after the power station at Żydowo was set in operation). Pol. Arch. Hydrobiol. 24: 147–154.

Minderhoud J. W., 1978. Pseudostolons and aerial tillers: morphological phenomena of *Lolium perenne* L. Europ. Grassld. Fed. 7th Gen. Meet., Gent (Belgium).

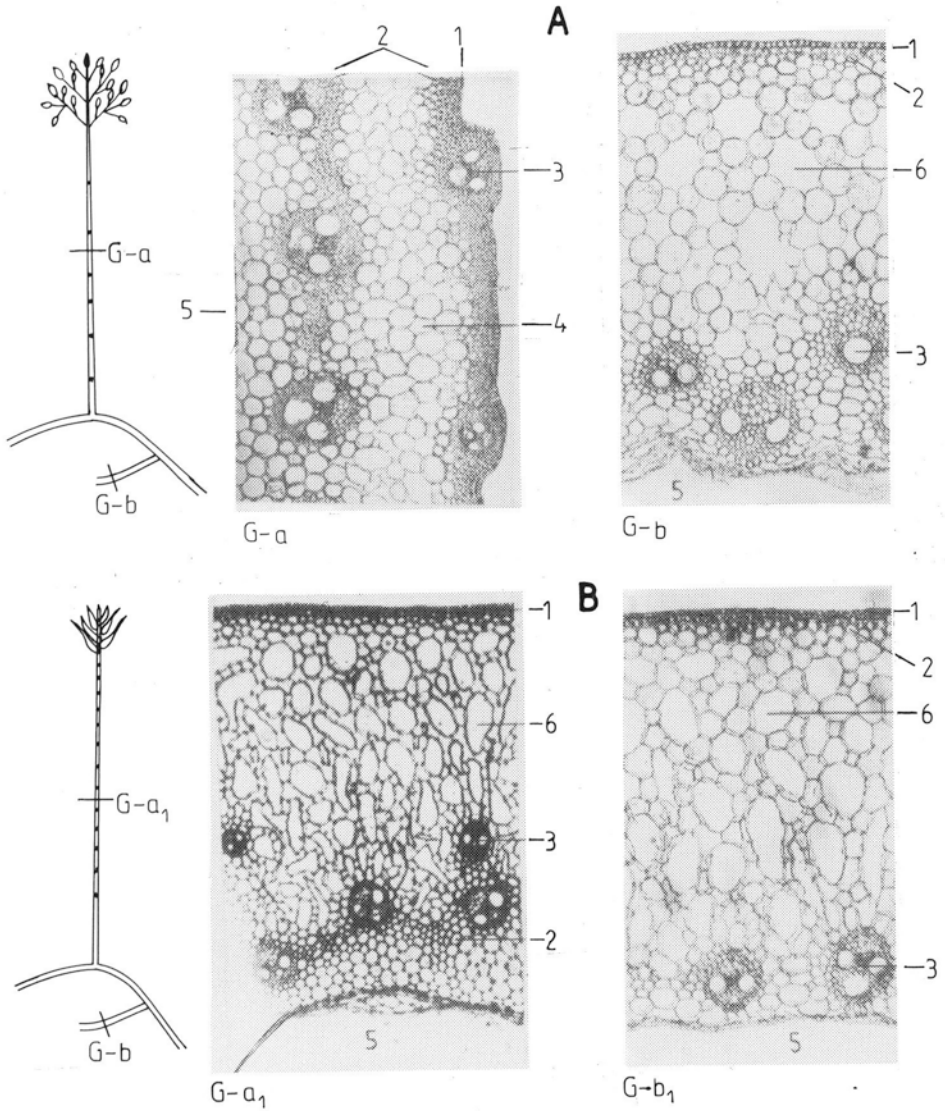

Fig. 2. *Glyceria aquatica* (L.) Wahlb. A — cross section through generative shoot (G-a) (× 82) and through rhizome (G-b) (× 110). B — cross section through vegetative shoot. ($G\text{-}a_1$) (× 90) and through rhizome ($G\text{-}b_1$) (× 130). 1 — epidermis, 2 — sclerenchyma, 3 — vascular bundles, 4 — parenchyma, 5 — pith channel, 6 — aerenchyma

Fig. 3. *Glyceria aquatica* (L.) Wahlb. form with stolons

Fig. 5. Aerial tillering on vegetative shoot of *Phalaris arundinacea* L.

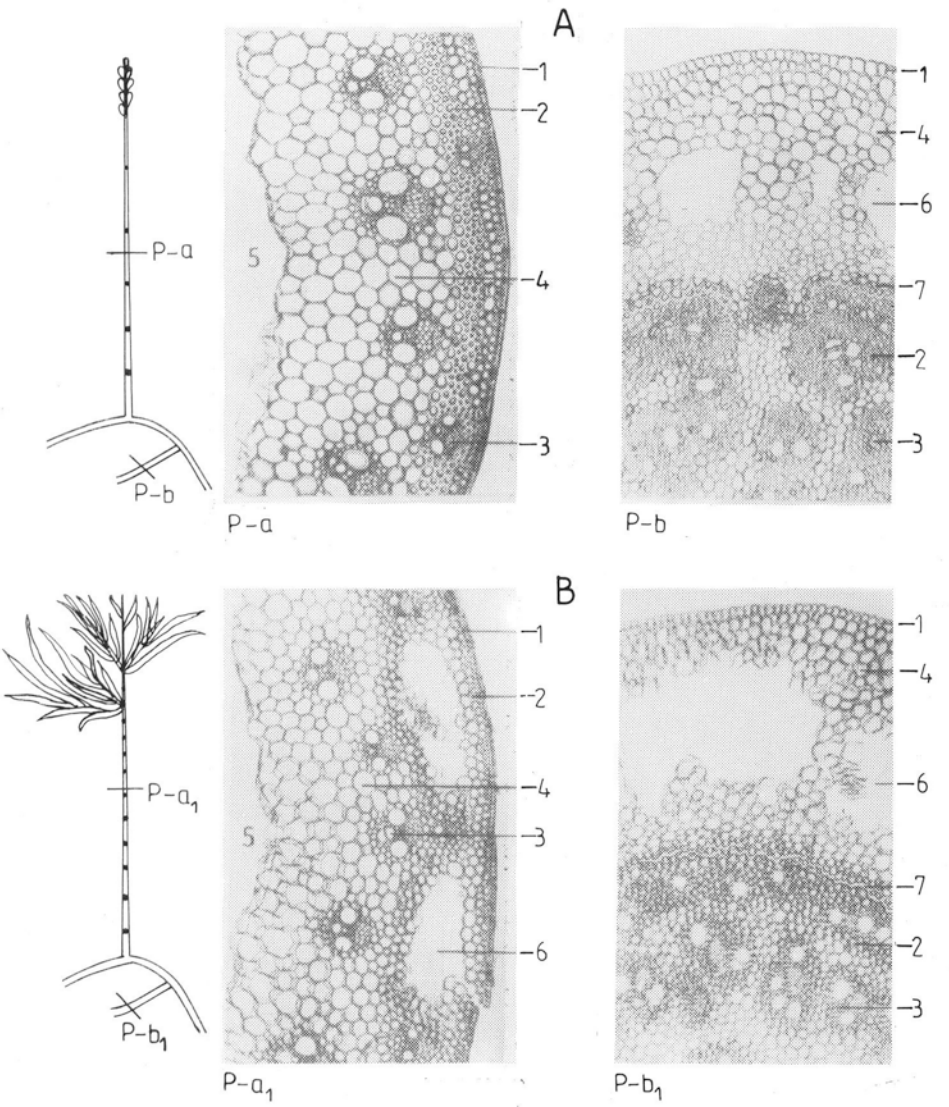

Fig. 4. *Phalaris arundinacea* L. A — Cross section through generative shoot (P-a) (× 150) and through rhizome (P-b) (× 80). B — Cross section through vegetative shoot ($P\text{-}a_1$) (× 150) and through rhizome ($P\text{-}b_1$) (× 80). 1 — epidermis, 2 — sclerenchyma, 3 — vascular bundles, 4 — parenchyma, 5 — pith channel, 6 — air channels, 7 — endoderm

Olszewska L., Wielicka M., 1981. Rozgałęzianie się pędów nadziemnych u niektórych traw. Acta Agrobot. 34: 53–68.

Olszewska L., Wielicka M., 1984. Dependence of anatomical structure features on morphological form of branching of grass shoots. Acta Agrobot. 37: 17–28.

Strebeyko P., 1971. Fitobiologia. PWN, Warszawa, pp. 251–264.

Śpiewakowski E. R., 1974. Badania nad zmianami w szacie roślinnej pod wpływem nierytmicznych wahań poziomów wody w zespole jezior Elektrowni Wodnej Żydowo. WSP, Słupsk, pp. 28–130.

Śpiewakowski E. R., 1977. Wstępne badania nad wpływem ruchów turbulencyjnych wody na plankton jezior Kamienno i Kwiecko. W: Ochrona i kształtowanie środowiska przyrodniczego Pomorza Środkowego. Wyd. WSP, Słupsk, pp. 59–69.

Śpiewakowski E. R., 1979. Zmiany szaty roślinnej okolic Żydowa jako wynik antropopresji. Wyd. WSP, Słupsk. Koszaliński Ośrodek Naukowo-Badawczy, Słupsk-Koszalin, pp. 43–58.

Śpiewakowski R. E., Korczyński M., Korczyńska E., 1985a. Wstępne wyniki badań nad opracowaniem metody zabudowy roślinnej stref zalewowych jezior Elektrowni Wodnej Żydowo. Koszalińskie Studia i Materiały. 47: 42–56.

Śpiewakowski E. R., Piasecki J., Wielicka M., 1985b. Morphological and anatomical changes in the petioles of *Nymphaea alba* L. and *Nuphar luteum* (L.) Sm. caused by oscillations of the water level in lakes. Acta Soc. Bot. Pol. 54: 351–359.

Zmiany morfologiczno-anatomiczne u Glyceria aquatica (L.) Wahlb. i Phalaris arundinecea L. rosnących w strefie zalewowej jez. Kwiecko

Streszczenie

W pracy przedstawiono zmiany morfologiczno-anatomiczne pędów *Glyceria aquatica* i *Phalaris arundinacea*. Trawy te wkraczają na tereny strefy zalewowej jez. Kwiecko, stanowiącego dolny zbiornik Elektrowni Wodnej Żydowo. Wyhania dobowe lustra wody w jez. Kwiecko przy maksymalnym piętrzeniu wynoszą 3,1 m. Zespół czynników siedliskowych i antropogenicznych powoduje zakłócenia w filozofii rozmnażania u wymienionych gatunków roślin, jak również wywołuje zmiany w ich strukturze zewnętrznej i wewnętrznej. Obydwa gatunki w strefie zalewowej jez. Kwiecko tworzą wyłącznie pędy wegetatywne z bogatym powietrznym krzewieniem w merystemach wierzchołkowych. Dalsze zmiany dotyczą skrócenia długości pędów oraz zwielokrotnienia międzywęźli. Innym objawem przystosowania się do dużych wahań poziomu lustra wody w jez. Kwiecko jest zmniejszenie pierścienia sklerenchymy, przesunięcie wiązek przewodzących w głąb aerenchymy, zwiększenie objętości aerenchymy i kanałów powietrznych. Elastyczność budowy charakteryzowanych gatunków, ich adaptacja do warunków strefy zalewowej jez. Kwiecko pozwala spełniać rolę biologicznej zabudowy powierzchni strefy zalewowej narażonej na duże wahania poziomu lustra wody w zbiorniku.