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The International Society for Plant Anaerobiosis: History, Functions and Activity

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The International Society for Plant Anaerobiosis (ISPA) was founded to promote and coordinate research on higher plant responses to hypoxic and anoxic stresses. The original goal of the Society was to organize regular meetings and discussions between scientists involved in this research and to encourage publication of monographs and papers in periodicals on plant life under low-oxygen stress conditions.

The activities of ISPA members commenced immediately following the First International Symposium on Plant Anaerobiosis held within the framework of the XII International Botanical Congress in Leningrad (St. Petersburg) in 1975, although the ISPA itself was formally established somewhat later. In the 1970s so few researchers were involved in studies on higher plant anaerobic stress that it was not easy to organize a special symposium dedicated to this specific topic. Even when a core of several key speakers was finally assembled, we still faced the equally difficult task of persuading the principal organizers of the International Congress to dedicate a special symposium to this subject. It was not easy for them to agree, because no previous international congresses, conferences or symposia, on botany, biochemistry, or agriculture, had paid particular attention to this topic, and no books devoted to the subject of plant anaerobic stress had yet been published. Thanks to Academician A.L. Kursanov, a vice-president of the XII International Botanical Congress, who backed the appeal to the Congress, the symposium on anaerobic stress was finally added to the scientific programme of the Congress. As a result, several invited researchers in this field, including R.M.M. Crawford and W. Armstrong (UK), A. Pradet (France), H. Tsuji (Japan), S. Leblova (Czechoslovakia at that time), D.D. Hook (USA) met for the first time and took part in the symposium.

After a successful symposium at a final evening party held in "Astoria" hotel restaurant, the idea was advanced to publish the proceedings of the symposium as a book. The participants enthusiastically welcomed this proposal. Based on the symposium papers, the first book was published on higher plant life under anaerobic stress in the USA (Hook and Crawford 1978). The book met with much interest from the scientific community, as reflected by numerous reviews published in leading international journals, such as *Science*, *New Phytologist*, and the *Journal of Applied Ecology*. The first edition of the book soon sold out, and a second printing appeared in 1980. As mentioned in a later monograph on plant anaerobic stress *Plant Life under Oxygen Deprivation* (Jackson, Davies, Lambers 1991), the Hook and Crawford volume had been "without doubt, a most influential publication and inspiration for much subsequent research".

This first symposium and the first book edited by D. Hook and R. Crawford on plant anaerobic stress helped to unite the small group of researchers already active in this field to promote the development of new research groups and centres involved in the study of plant hypoxic and anoxic stresses. Close international contacts were now established between researchers that resulted in joint studies and publications. In this way, the first symposium and the first book on plant anaerobic stress became the basis for the foundation both of a new scientific society (ISPA) that was officially established by the members of the Second International Symposium that took place in Moscow in 1985 and provided a platform for a new scientific discipline embracing plant life under hypoxic and anoxic stresses. The Society's published a regular newsletter.

Fifteen international symposia and conferences were subsequently initiated by ISPA members on a regular basis in various countries, sometimes under the aegis or financial support of UNESCO, NATO or Green Cross (**Table 1**). The level of participation in these meetings increased notably over time with the Second International Symposium on anaerobic stress (held in Moscow in 1985 and funded by UNESCO) attracting several times more researchers than did the first symposium in 1975. Subsequent ISPA conferences in Finland (1995), Netherlands (2001) and in Australia (2004) brought together almost a hundred delegates from Europe, Asia, Australia, and North America. In addition to these international meetings, many hundreds of scientific papers have vividly illustrated the growing interest in the phenomenon of plant anoxic and hypoxic stresses and related topics connected with flooding and submergence. Thanks to the efforts of ISPA members, numerous influential monographs and collections of papers have now been published on these topics (**Table 2**). A special chapter dedicated to plant anaerobic stress was included in volume 2 of *The Biochemistry of Plants* (Davies 1980) followed by a chapter in the *Encyclopaedia of Plant Physiology* (Crawford 1982). The importance of studies on plant aeration problems was thus becoming recognized in basic plant biology and in applied agronomy and forestry with both economic and ecological dimensions of this problem being increasingly acknowledged. The subject of plant anaerobiosis has been included in the scientific programmes of International Conferences including "Rice Production on Acid Soils of the Tropics" (1989, Sri Lanka), the First International Crop Science Congress (1992, USA), and the International Botanical Congresses in Yokahama, Japan (1993) and St Louis, USA (1999). Other notable conferences included the 1993 meeting of the Royal Society of Edinburgh in St Andrews, Scotland (see Crawford *et al.* 1994) and the 1998 Annual Meeting of the American Society of Agronomy/Crop Science/Soil Science held in Minneapolis. ISPA members either organized these sessions or participated in them as invited speakers. The papers presented at more recent meetings have been regularly edited by Professor Jackson, the present President of ISPA, and published in special issues of the *Annals of Botany*.

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Scientific Note

Table 1 International symposia and conferences organized by ISPA members.

Year	Country	Organizers
1975	USSR (XII IBC)	B.B. Vartapetian
1985	USSR (UNESCO)	B.B. Vartapetian
1985	United Kingdom	R.M.M. Crawford
1986	United States	D.D. Hook
1987	Switzerland	R. Brändle
1992	Iceland (UNESCO)	B.E. Gudleifsson
1992	United Kingdom (NATO)	M.B. Jackson, C.R. Black
1993	Japan (XV IBC)	M.B. Jackson
1994	United Kingdom	R.M.M. Crawford
1995	Finland	S. Pulli, B.V. Fagerstedt
1995	United Kingdom (SEB)	M.B. Jackson
1998	USA	T.T. VanToai
1999	USA (XV1 IBC)	J.L. Seago, W. Armstrong
2001	The Netherlands (Green Cross)	A.C.J. Voesenek, E.J.W. Visser, M.B. Jackson, C.W.P.M. Blom
2004	Australia	T.D. Colmer, H. Greenway, T.L. Setter
2007	Japan (in preparation)	K. Ishizawa

Table 2 Monographs and collected papers on plant hypoxic and anoxic stresses, edited and published by ISPA members.

Year	Title, Publishing house	Editors
1978, 1980	*Plant Life in Anaerobic Environments*, Ann Arbor Science, Michigan (1st, 2nd Edns)	D.D. Hook, R.M.M. Crawford
1987	*Plant Life in Aquatic and Amphibious Habitats*, Blackwell, Oxford	R.M.M. Crawford
1988	*The Ecology and Management of Wetlands*, Croom Helm, London	D.D. Hook *et al*.
1991	*Plant Life under Oxygen Deprivation*, SPB Academic, The Hague	M.B. Jackson, D.D. Davies, H. Lambers
1993	*Interacting Stresses on Plants in a Changing Climate*, NATO ASI series, Springer-Verlag, Berlin	M.B. Jackson, C.R. Black
1994	*Oxygen and Environmental Stress in Plants*, *Proceedings of the Royal Society, Edinburgh Series B* **102**	R.M.M. Crawford, G.A.F. Hendry, B.A. Goodman
1994	Special Section of *Annals of Botany* **74**	M.B. Jackson
1997	Special Issue of *Annals of Botany* **79**	M.B. Jackson
2002	Special Section of *Annals of Botany* **90**	N. Smirnoff
2003	Special Issue of *Annals of Botany* **91**	E. Visser, L.A.C.J. Voesenek, M.B. Jackson
2003	Special Issue of *Russian Journal of Plant Physiology* **50**	B.B. Vartapetian
2005	Special Issue of Annals of Botany **96**	M.B. Jackson

Today, a comparison of the 1978 Hook and Crawford monograph with papers from prominent research teams published in special issues of *Annals of Botany* (2003 and 2005) and the *Russian Journal of Plant Physiology* (2003) gives a clear indication of the evolution and progress that has taken place in intervening 25-30 years. While earlier studies were mainly focused on the ecological, physiological, and biochemical aspects of plant anaerobic stress, the current studies have actively involved also molecular biology and molecular genetics. Such experimental studies exploit the now widely accepted concept of two principal strategies of plant adaptation to anaerobic stress (Vartapetian 1978), namely, adaptation at the molecular level, when in the case of the absence or deficiency of oxygen, cell metabolism is fundamentally rearranged (**true** tolerance) and, adaptation at the whole-plant level due to oxygen transport from the aerated parts into the organs (roots, rhizomes) localized in the anoxic medium, that is, the strategy of avoidance of the anaerobic conditions or **apparent** tolerance.

Although many biochemical processes are radically rearranged in these responses to hypoxia and anoxia, it is now widely accepted that energy metabolism, controlled and regulated at transcriptional, translational and post-translational levels resulting in selective synthesis of anaerobic stress proteins (mainly enzymes of fermentation and related processes of carbohydrate metabolism as well as aerenchyma formation) have key role in plant metabolic adaptation to the anaerobic environment.

The study of plant anaerobiosis has made remarkable advances on two fronts. On one hand, the ecological aspects of anaerobiosis are now better understood and shown to present problems that differ in their nature from those encountered in relation avoiding anoxic injury in crop plants. Ecologically, the nature of anoxia-tolerance is largely seasonal and often prolonged. It also takes place at a time of year, and under conditions where plastic growth responses are unable to provide avoidance mechanisms. The most extreme example is encountered in the Arctic where encasement in ice can deprive the native vegetation of access to oxygen for up to eight months in the year. With current global warming trends this danger is increasing as more frequent periods of warm weather at high latitudes result in rain falling on the frozen tundra which then turns to ice which prevents all access to oxygen.

The adaptations for prolonged periods of flooding or ice-encasement outside the growing season depend on the down-regulation of metabolism, coupled with a robust metabolic defense with anti-oxidants against post anoxic injury, to prevent tissue-damage when water tables fall and ice melts in the spring. By contrast, flooding during the growing season for crop plants is usually episodic, of limited duration, and takes place at a time when plants grow, and therefore have the capacity to respond both morphologically and physiologically to oxygen-deprivation (Crawford 2003).

Biotechnologists working with crop plants therefore pursue a different range of adaptations from those explored by physiological ecologists working with natural vegetation. In crop research attempts are now being made to create plants more tolerant to anaerobiosis by genetic engineering and clonal selection of tolerant cell lines *in vitro* in order to regenerate plants tolerant to soil anaerobiosis. Current studies of plant anaerobiosis employ the large inventory of modern physical and chemical methods and technologies. Members of ISPA who organized or participated actively during past decades, both in regularly arranged symposia and conferences of Society, and in publications of the papers in monographs, and special issues of periodic journals, have played an important role in establishing and consolidating this branch of science.

Thus, the labours and efforts of the older generation of researchers on plant anaerobiosis laid a solid basis for a new scientificfic discipline. The thirty years' activity of ISPA members have been instrumental in attracting the attention of the international scientific community to the issue of plant life under poorly aerated conditions. It is mainly thanks to ISPA members' activities that new laboratories and scientific centres became engaged in studies of the ecological, physiological, biochemical, molecular biological, and molecular genetic aspects of the phenomenon of plant anaerobic stress have sprung-up across the World. We feel justified in maintaining that, in addition to traditional branches of ecological physiology and biochemistry, embracing drought, cold, heat, saline and biotic stress factors, a new independent avenue for study of plants under low-oxygen stress has appeared and gained international recognition. An honourable task for the new generation of researchers of plant anaerobiosis is to receive the relay baton from the hands of their elders and move forward to clarify, the molecular mechanisms of plant damage and adaptation under hypoxic and anoxic conditions. The elucidation of basic processes underlying plant responses to anoxia, an issue currently involving research teams in many countries, would help in taking the next step of creating crop plants with the potential to tolerate to anaerobic stress and protect the environment.

Founder members of ISPA from left to right; Professors Robert Crawford, Boris Vartapetian, and William Armstrong. Photograph taken at the ISPA meeting in Nijmegen (Netherlands) in 2001.

REFERENCES

Crawford RMM (2003) Seasonal differences in plant responses to flooding and anoxia. *Canadian Journal of Botany – Revue Canadienne de Botanique* **81**, 1224-1246

Davies DD (1980) Anaerobic metabolism and the production of organic acids. In: Davies DD (Ed) *The Biochemistry of Plants* (Vol 2), Academic Press, New York, pp 581-611

Jackson MB, Davies DD, Lambers H (Eds) (1991) *Plant Life UnderOxygen Deprivation*, SPB Academic Publishing, The Hague, The Netherlands

Vartapetian BB (1978) Introduction: life without oxygen. In: Hook DD, Crawford RMM (Eds) *Plant Life in Anaerobic Environments*, Ann Arbor Science, Michigan, pp 1-12