

Fifty plus years of the International Silage Conferences

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The early development of this series of Silage Conferences was outlined by Wilkins (1996) and Wilkins and Wilkinson (2015). This paper will provide an update on the Conferences, indicate the state of knowledge when the series started in 1970, outline how the major themes of the presented papers have changed over this period and discuss future opportunities and challenges. This is very much the personal perspective of a long-retired scientist who was involved in the planning of the first meeting and has attended all but one of the meetings. It is a good time for review as the formation of an International Silage Science Society at the next Conference in Florida will be another landmark in the development of this series of meetings.

Development of the Conferences The venues of the meetings and the number of participants are listed in Table 1. The 19th Conference in Beijing, scheduled for 2021, was postponed until 2023 because of the Covid-19 pandemic and involved, for the first time, an option for online participation as well attendance in person. The 20th Conference will be held at Gainesville, Florida, USA, in 2025.

Table 1. Years, venues, titles of meetings and number of participants

				Number participants
1	1970	Edinburgh, Scotland, UK	Silage Seminar	35
2	1972	Hurley, England, UK	Silage Seminar	63
3	1974	Edinburgh, Scotland, UK	Silage Conference	66
4	1976	Hurley, England, UK	Silage Conference	57
5	1978	Ayr, Scotland, UK	Silage Conference	81
6	1981	Edinburgh, Scotland, UK	Silage Conference	87
7	1984	Belfast, Northern Ireland, UK	Silage Conference	91
8	1987	Hurley, England, UK	Silage Conference	112
9	1990	Newcastle, England, UK	Silage Conference	103
10	1993	Dublin, Republic of Ireland	International Conference on Silage Research	150
11	1996	Aberystwyth, Wales, UK	International Silage Conference	203
12	1999	Uppsala, Sweden	International Silage Conference	229
13	2002	Auchincruive, Scotland, UK	International Silage Conference	204
14	2005	Belfast, Northern Ireland, UK	International Silage Conference#	193
15	2009	Madison, WI, USA	International Silage Conference	253
16	2012	Hameenlinna, Finland	International Silage Conference	328
17	2015	Piracicaba, SP, Brazil	International Silage Conference##	286
18	2018	Bonn, Germany	International Silage Conference	344
19	2023	Beijing, China	International Silage Conference	286###

Also Satellite Workshop of 20th International Grassland Congress

Also 4th International Symposium on Forage Quality and Conservation

Excluding the online participants - some 25 international delegates and over 3000 from China.

The first meeting was held in Edinburgh in 1970 and was entitled 'Silage Seminar'. There were 35 participants, all from the UK and Ireland. The five sessions covered: (i) Ensiling characteristics and pre-treatment of herbage, (ii) Biochemical changes during ensilage, (iii) Losses during ensilage, (iv) Nutritional value of silage, (v) The future of conservation. There were no formal papers, but each session involved a panel of three or four researchers. They outlined their recent findings and future plans and this was followed by a full discussion of the topic.

Meetings were then held at two or three year intervals in different centres in the UK until the 10th meeting in Dublin in 1993. The format gradually evolved to become a conference built around offered papers reporting recent research and development, together with a small number of invited contributions. Although summaries of most of the papers were available at the early meetings, a collated collection of papers was not produced until the 5th meeting at Ayr in 1978 and full Proceedings were not published until the 10th meeting at Dublin in 1993. Copies of reports of early meetings and published proceedings of subsequent meetings can be accessed through the websites for ISC Beijing and Florida.

Attendance at the first meeting was by invitation only and was restricted to people working in the public sector. This limitation to the public sector continued, with few exceptions, until the 10th meeting. From the second meeting a number of scientists from other, mainly European, countries were invited, but the meetings were not fully open until Dublin in 1993.

The meeting in Dublin was a landmark meeting. Not only was it the first with open attendance, but it was also the first to have fully published Proceedings. This pattern has continued to the present, with meetings generally held at three-year intervals. The venues became intercontinental. The first meeting outside of the UK and Ireland was in Sweden in 1999. Meetings outside of Europe have been in USA in 2009, Brazil in 2015 and Beijing in 2023. Attendance exceeded 200 for the first time in Aberystwyth in 1996. The highest in-person attendance (344) was at Bonn in 2018, but the highest total participation was in Beijing in 2023. Not surprisingly, the geographical distribution of the delegates changed with time and with the location of a particular meeting (see Annex 1). There were only one or two delegates from outside of Europe in each of the meetings held between 1976 and 1984, but this increased to 30 - 114 at meetings held in Europe from 1996 to 2018 and, not surprisingly, was much higher for the meetings in USA (170), Brazil (214) and China (233). A domestic UK and Ireland meeting has developed into a truly global forum for reporting and discussing silage research. The participation from Africa and Australasia has, however, remained low, reflecting the lesser importance of silage in animal feeding in those continents at present.

The continuation of meetings has been achieved with a minimum of formality. A group comprising lead organisers of previous meetings has made decisions on the venue for the next meeting. This group, sometimes called the ‘silage mafia’, was identified as the Continuation Group during the closing session of the 17th ISC in 2015 and a more formal procedure for applications to be made to host succeeding meetings was introduced. Throughout the series, the host country has had financial responsibility for their meeting and there has been no continuing funding. When established, the International Silage Science Society (see below) will take on responsibility for the continuation of the meetings.

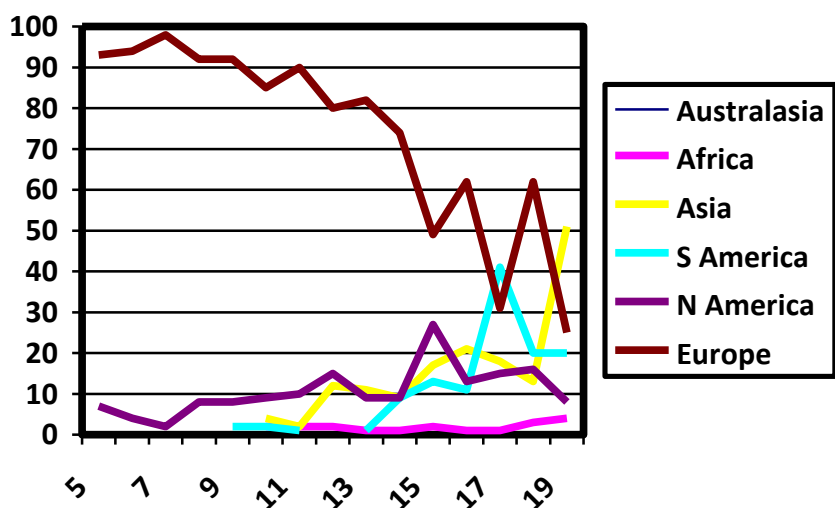


Figure 1 Contribution of continents to authorship of papers at meetings 5 to 21 (% of papers; totals may exceed 100 as some papers had authors from more than one continent).

Table 2 lists the countries with most papers overall and in three phases of evolution of the ISC. This shows the predominance of contributions from the UK in the first phase when it was a closed meeting, followed by greater diversification in the second phase when meetings were held in different European countries and in the third phase the large contributions from Brazil, Germany and China, hosts of the three most recent meetings. The only countries that ranked in the top ten in each of the three phases were Finland, Germany, Sweden, UK and USA. The complete list of papers by countries is given in Annex 2 and the countries contributing most papers to individual meetings is given in Annex 3.

Table 2 Countries contributing most papers to meetings in different phases of evolution of ISC

1972-90 #		1993-2005##		2009-2023###		Overall	
UK	244	UK	173	Brazil	210	UK	459
Ireland	22	Germany	61	China	196	Germany	247
Germany	18	Finland	57	Germany	168	Brazil	221
Netherlands	18	USA	54	USA	137	USA	201
Finland	12	Ireland	52	Finland	53	China	197
Sweden	12	Sweden	47	Japan	47	Finland	122
France	10	Japan	26	Sweden	44	Sweden	103
USA	10	Poland	19	UK	42	Ireland	98
Canada	8	Italy	18	Italy	36	Japan	74
Belgium	5	Netherlands	17	Denmark	34	Italy	57

All meetings were held in the UK with some scientists from other countries invited to attend and contribute papers.

Meetings open to all, but all held in Europe

The first meeting to be held outside of Europe was in USA in 2009. Subsequent meetings in this period were in Finland, Brazil, Germany and China

A feature of the series has been the contributions from researchers with many different disciplinary backgrounds. Successful systems of forage conservation and feeding require inputs from agronomists, engineers, chemists, biochemists, microbiologists, physicists, mathematicians, animal nutritionists, animal production specialists, veterinarians and economists. Teams with the capability of integrating information from these different disciplines are needed. The Conferences have provided a forum for people from these disciplines to meet and interact and these contacts stimulated the development of several successful international inter-disciplinary research projects, including Eurowilt (Zimmer and Wilkins, 1984), Eurobac (Lindgren and Petterson, 1990) and Legsil (Wilkins and Paul, 2001).

Industry has made key contributions to silage research, the application of research findings and to the success of recent International Silage Conferences. This was particularly marked at the 19th Conference in Beijing where 53 of the 96 delegates from outside of China were from commercial companies, rather than academic Institutions.

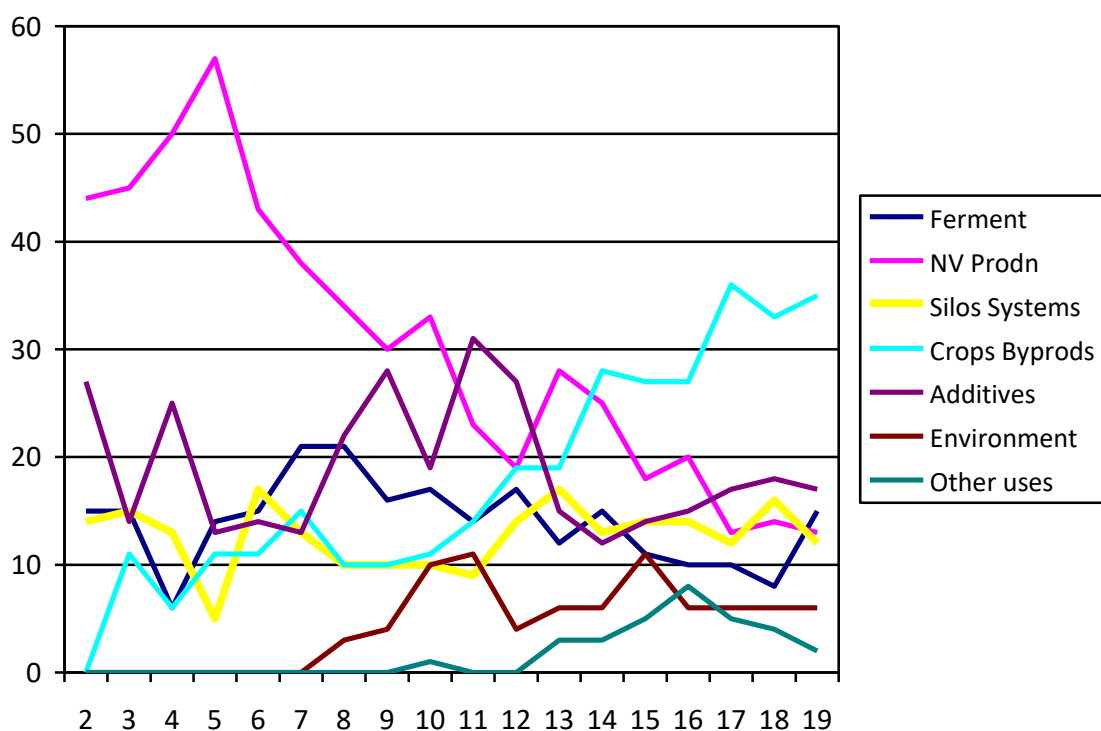
State of knowledge in 1970 Papers by Zimmer (1969) and Raymond (1969) in the Proceedings of the 3rd General Meeting of the European Grassland Federation held in Braunschweig in 1969 on 'Crop Conservation and Grassland' present a good account of knowledge and the issues being studied at that time. Major biochemical pathways involved in silage fermentation had been identified and the importance of the contents of dry matter, water-soluble carbohydrates and buffering capacity in influencing the course of fermentation was recognised. The magnitude of losses in the field and in the silo had been quantified and it was realised that losses could vary greatly according to method of ensiling and particularly the dry matter content at ensiling. The main thrust of research on additives was on the use of formic acid and salts, although Gross (1969) reported favourable results with inocula of lactic acid bacteria, particularly when added at high rates. Whilst the digestibility of silages had been shown to generally be similar to that of the crop prior to ensiling, animal outputs from silage-based diets were often disappointing because of low levels of feed intake, but the factors limiting intake had not been elucidated.

Themes at Silage Conferences There has always been a broad mix of contributions to the Conferences, with the contributions reflecting the research activity in progress at the time of the meeting.

Figure 2 illustrates the large changes in balance that have taken place. Wilkins and Wilkinson (2015) identified three phases. The first meetings (1 to 5) were dominated by contributions relating to the silage fermentation, the determinants of feeding value of silage and sources of loss, with about half of the papers being concerned with aspects of feeding value. This work provided a scientific basis for production of silage on farms. Linked with progress in mechanisation and the availability of polythene sheeting, silage was able to be made on farms reliably and with high feeding value. A rapid increase in silage making took place with silage replacing hay as the major conserved forage in UK, the venue of these meetings, and throughout much of Europe.

The main thrusts of the next series of meetings (6 to 11) concerned aerobic deterioration (a problem that had increased following better control of the anaerobic fermentation), inoculation, the prediction of feeding value and feed complements for silage. The third phase (meetings 12 to 19) was typified by increased diversity in the contributions, reflecting increased size of meetings and wider global participation. Many papers during this phase focussed on the ensiling and use of silages from a wide range of materials, including tropical forages, moist grains/seeds and by-products, with this category accounting for more than 30% of the total number of papers. Research on grasses, legumes and whole-crop cereals, particularly maize, has included more studies on the development and evaluation of whole systems of animal production, including increasing concern with effects on hygiene, health and impact on the environment. At the most recent meeting in China there was an upturn in the number of papers focusing on fermentation in the silo, often involving the application to ensiling of new techniques of metabolomics and metagenomics and new approaches for studying the microbiome.

Figure 2. Main topics of papers presented to Silage Conferences (%)



Category	Papers with primary focus on:	Category	Papers with primary focus on:
Ferment	Fermentation, deterioration	Additives	Additives
NV Prodn	Nutritive value, ruminant production	Environment	Environment, hygiene, safety
Silos Systems	Silos. mechanisation, losses, systems	Other uses	Non-ruminants, biogas, biorefinery
Crops byprods	Crops, by products		

The use of silage for biogas, first featured in the 15th Conference in 2009, opened up a whole new area of research, as previous contributions had been concerned almost exclusively with producing silages for domesticated ruminant animals. There had, however, been a paper by Henderson and Whittemore (1976) on feeding silage to pigs and a poster session on feeding silage to horses at Auchincruive in 2002. A further example of diversification has been papers involving ensiling in the biorefining of forages, with the opportunities reviewed by Rinne (2023) in Beijing.

Challenges and opportunities There are challenges and opportunities ahead both for silage production and utilisation and for the International Silage Conferences.

Silage production and utilisation Review papers presented at the most recent ISCs in Bonn and Beijing provided excellent assessments of the state of current knowledge and future challenges (Davies et al., 2018; Nair et al., 2018; Nussio and Daniel, 2023; Vyas and Adesogan, 2023; Wilkinson and Muck, 2018). Although much progress has been made, there remain requirements to reduce energy inputs and costs, increase the predictability of silage making and feeding and improve the hygienic quality, aerobic stability and nutritive value of silages.

Rapid progress is being made in the development of sensors, drones and robots to enable a precision farming approach to be applied to silage making, with in-line assessments of the chemical and microbial status of crops facilitating the identification and use of appropriate wilting and additive treatments. Biotechnological advances and knowledge derived from metabolomics, metagenomics and studies of the microbiome are increasing our understanding of the changes that occur during ensiling and will aid the development of improved additive treatments.

Further progress is required to enhance the feeding value of silages. Whilst improvements in technology have meant that severe reductions in the voluntary intake and protein value of silages can now be avoided, there remains a challenge to produce silages with higher feeding value than that of the crop before ensiling. The use of ferulic acid esterase to improve fibre digestibility and intake potential is giving promising results. Efforts are continuing to improve protein value through the use of crops containing tannins or polyphenol oxidase or additives to reduce protein breakdown in the silo or the rumen. Figure 2 shows that the proportion of papers presented at ISCs that focus on nutritive value and animal production has progressively declined. It is crucial that results on altered silage quality are confirmed using animal trials before final conclusions and recommendations are made.

Although the main purpose of ensiling is to preserve the original crop for year-around use with minimal losses and without the proliferation of undesirable organisms, the fermentation phase can in some cases be considered as a pre-treatment that decreases the amounts of harmful microbes, degrades antinutritional compounds, or facilitates further processing in a green biorefinery.

Wilkinson and Muck (2018) gave a fascinating image of 'Ensiling in 2050' at the Bonn ISC. They highlighted the potential for application on farms by that time of: (i) Drone or satellite information at or directly before harvest on nutritive characteristics, mycotoxins, populations of lactic acid bacteria and contents of WSC, DM and of undesirable nutritive characteristics, (ii) Robotic harvesting of forages, using drone information to potentially separate the crop (eg high/low mycotoxins, high/low DM etc.) and possibly change the type or amount of additive used, (iii) Robotic transport of forage from the field to the silo. This will free up labour to control the filling and packing of silos and piles. (iv) The use of equipment to receive forage from the field and distribute it onto the surface of a silo or pile in thin layers, (v) Silage additives that consistently improve fibre and nutrient availability to livestock compared to that of the harvested crop. (vi) Silage additives that reduce or eliminate mycotoxins that enter the silo on the harvested

crop. (vii) Silo and pile covers that can be re-used for many years. (viii) Robotic emptying of bunkers or piles, keeping a smooth face with use of sensors that can recognize and divert spoiled silage.

Sustained effort in silage research and development will be required to fully realise these opportunities, to facilitate novel uses of silage that may arise from the development of biorefining and the use of new crops and by-products and to use AI to improve the precision and predictability of systems for making and using silage.

International Silage Conferences and International Silage Science Society With these possibilities ahead, there are exciting challenges for all involved in silage research and development. The ISCs will have a continuing key role in achieving dissemination of new research findings.

With increased costs of long-distance travel and concerns on its environmental impacts, consideration will have to be given to the format of ISCs and methods of participation. The Conference in Beijing in 2023 was a hybrid meeting with both 'in person' and 'online' participation. This structure was adopted because of problems arising from the covid pandemic, but may be the pattern for the future. I personally though have gained much from the informal contacts that can be developed during the course of 'in person' meetings, particularly interactions with scientists from different disciplines. Thought must be given to ways to encourage and facilitate such interactions should the primary method of participation be 'online'

The formation of the International Silage Science Society in Florida in 2025 (see the website for the Beijing ISC, <https://www.isc2021.cn>) will provide a more formal framework for the organisation and promotion of International Silage Conferences.

Steps are already being made to establish a new Journal devoted to silage research. This will provide a focus for publication of research on all aspects of silage production and utilisation. Much silage research is multidisciplinary, but at present papers are dispersed between a wide number of journals, generally oriented towards specific disciplines. The Editorial Boards of these journals often lack appreciation of the importance and particular features of inter-disciplinary research and methodology in ensiling experiments.

The formation of ISSS will also give enhanced opportunities for fostering international collaborations in research and development, particularly through funding from international agencies. The involvement of researchers, extension specialists and industry will continue to be crucial to maximise technology interaction and achieve the rapid adoption of research findings.

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It has been my privilege to have been a member of the silage research community for many years. I thank all those with whom I have interacted during this period for their help and friendship. The International Silage Conferences have been particularly important in developing these contacts.

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References

Davies, D.R., Thomson, A.L. and Borreani, G. (2018). New technologies to monitor and improve silage quality from field to feed-out. *Proceedings XVIII International Silage Conference, Bonn, 438-50.*

- Gross, F. (1969). Steuerung des Gaerverlaufs durch Zusatzmittel [Influence of additives on fermentation processes]. *Proceedings 3rd General Meeting European Grassland Federation*, Braunschweig, 139-45.
- Henderson, A.R. and Whittemore, C.J. (1976). Cellulase-treated silage for pigs. Paper presented at 4th Silage Conference, Hurley.
- Lindgren, S. and Petterson, K.L. (eds) (1990). Proceedings of the Eurobac Conference, *Grass and Forage Reports No, 3*, Swedish University of Agricultural Sciences.
- Nair, J., McAllister, T.A., Duniere, L., Xu, S., Drouin, P., Checaux, E., Zaheer, R., Munns, K., Smiley, B., Rutherford, E., Qi, S. and Wang, Y. (2018). *Proceedings XVIII International Silage Conference*, Bonn, 104-16.
- Nussio, L.G. and Daniel, J.L.P. (2023). Advances and opportunities for silage research. *Proceedings XIX International Silage Conference*, Beijing, 1-12.
- Raymond, W.F. (1969). The evaluation of forage crops for conservation. *Proceedings 3rd General Meeting European Grassland Federation*, Braunschweig, 53-8.
- Rinne, M. (2023). Novel uses of ensiled biomasses as feedstocks for green biorefineries. *Proceedings XIX International Silage Conference*, Beijing, 79-88.
- Vyas, D. and Adesogon, A.T. (2023). Smart silage of the future. *Proceedings XIX International Silage Conference*, Beijing, 89-94.
- Wilkins, R.J. (1996). Silage production and utilisation – perspectives from Silage Research Conferences, *Proceedings 11th International Silage Conference*, Aberystwyth, 1-10.
- Wilkins, R.J. and Paul, C. (eds) (2001). Legume silages for animal production – LEGSIL, *Landbauforschung Voelkenrode*, 234, 95 pp.
- Wilkins, R.J. and Wilkinson, J.M. (2015). Major contributions in 45 years of International Silage Conferences. *Proceedings XVII International Silage Conference*, Piracicaba, 26-49.
- Wilkinson, J.M. and Muck, R.E. (2018). The future of ensiling: challenges and opportunities. *Proceedings XVIII International Silage Conference*, Bonn, 2-15.
- Zimmer, E. (1969). Biochemische Grundlagen der Einsaeuerung [Biochemical principles of ensiling]. *Proceedings 3rd General Meeting European Grassland Federation*, Braunschweig, 113 -25.
- Zimmer, E. and Wilkins, R.J. (eds) (1984). Efficiency of silage systems: a comparison between wilted and unwilted silages. *Landbauforschung Voelkenrode*, 69, 88 pp.

ANNEX 1

Continent of delegates at International Silage Conferences

			Total delegates	Number from Continents					
				Europe	North and Central America	South America	Asia	Africa	Australasia
2	1972	Hurley, England	63	63					
3	1974	Edinburgh, Scotland	66	65			1		
4	1976	Hurley, England	57	56	1				
5	1978	Ayr, Scotland	81	80	1				
6	1981	Edinburgh, Scotland	97	95	1		1		
7	1984	Belfast, Northern Ireland	91	90	1				
8	1987	Hurley, England	112	104	7		1		
9	1990	Newcastle, England	103	97	6				
10	1993	Dublin, Ireland	150	131	8		5	2	2
11	1996	Aberystwyth, Wales	203	173	12	2	8	4	4
12	1999	Uppsala, Sweden	229						
13	2002	Auchincruive, Scotland	204	165	14	2	12	4	6
14	2005	Belfast, Northern Ireland	193						
15	2009	Madison, USA	253	83	127	25	15	3	
16	2012	Hameenlinna, Finland	328	246	23	23	26	10	
17	2015	Piracicaba, Brazil	286	72	29	163	14	6	3
18	2018	Bonn, Germany	344	230	45	31	28	7	3
19	2023	Beijing, China	286	56	11	10	202	7	

ANNEX 2

Complete list of contributions from countries in different phases of Silage Conferences

	72-90#	93-05##	09-23###	Total		72-90	93-05	09-23	Total
EUROPE					N. AMERICA				
Austria	0	6	17	23	Canada	8	7	16	31
Belarus	0	0	1	1	Mexico	0	0	17	17
Belgium	5	3	8	16	Nicaragua	0	0	1	1
Bulgaria	0	1	0	1	Puerto Rico	0	0	8	8
Czech Republic	0	12	16	28	USA	10	54	137	201
Denmark	4	1	34	39	Total	18	62	181	261
Estonia	0	11	8	19	S. AMERICA				
Finland	12	57	53	122	Argentina	0	1	10	11
France	10	7	27	44	Brazil	0	11	210	221
Germany	18	61	168	247	Chile	1	4	1	6
Greece	0	0	1	0	Colombia	0	0	16	16
Hungary	0	2	13	15	Peru	0	0	1	1
Iceland	0	2	0	2	Total	1	16	238	255
Ireland	22	52	24	98	ASIA				
Italy	3	18	36	57	China	0	1	196	197
Latvia	0	3	1	4	India	0	2	2	4
Lithuania	0	6	20	26	Indonesia	0	0	3	3
Netherlands	18	17	13	48	Iran	0	0	15	15
Norway	3	13	10	26	Israel	2	12	2	16
Poland	3	19	15	37	Japan	1	26	47	74
Portugal	0	2	2	4	Kazakhstan	0	0	1	1
Russia	0	1	1	2	Korea	0	3	10	13
Slovakia	0	2	7	9	Kuwait	0	1	0	1
Spain	1	4	4	9	Laos	0	0	3	3
Sweden	12	47	44	103	Malaysia	0	2	0	2
Ukraine	0	1	0	1	Myanmar	0	0	1	1
UK	244	173	42	459	Pakistan	0	0	1	1
Total	357	528	579	1464	Sri Lanka	0	0	1	1
AFRICA					Thailand	0	0	9	9
Benin	0	1	0	1	Turkey	0	11	5	16
Egypt	0	1	2	3	Vietnam	0	0	1	1
Kenya	0	0	2	2	Total	3	58	297	358
Morocco	0	2	0	2	AUSTRALASIA				
Mozambique	0	0	2	2	Australia	0	4	1	5
Nigeria	0	0	6	6	Total	0	4	1	5
South Africa	0	3	9	12					
Zimbabwe	0	2	0	2					
Total	0	9	21	30	OVERALL TOTAL	379	677	1317	2373

All meetings were held in the UK with some scientists from other countries invited to attend and contribute papers.

Meetings open to all, but all held in Europe

The first meeting to be held outside of Europe was in USA in 2009. Subsequent meetings in this period were in Finland, Brazil, Germany and China

ANNEX 3

Countries contributing most papers to Conferences

1972, Hurley		1974, Edinburgh		1976, Hurley		1978, Ayr		1981, Edinburgh	
UK	15	UK	19	UK	18	UK	17	UK	31
Germany	3			Germany	2	Ireland	2	Germany	3
Finland	2							France	2
France	2							Netherlands	2
Ireland	2							Sweden	2

1984, Belfast		1987 Hurley		1990 Newcastle		1993, Dublin		1996, Aberystwyth	
UK	44	UK	64	UK	36	UK	36	UK	50
Ireland	5	Netherlands	6	Finland	5	Germany	14	Finland	10
France	3	USA	4	Netherlands	5	Finland	13	Germany	10
Sweden	3	Canada	4	Ireland	4	Ireland	11	USA	10

1999, Uppsala		2002, Auchincruive		2005, Belfast		2009, Madison		2012, Hameenlinna	
UK	29	UK	39	UK	19	USA	52	Germany	29
Sweden	15	Finland	14	Ireland	15	Germany	28	Finland	27
USA	13	Germany	13	Germany	13	Brazil	27	China	19
Germany	11	Ireland	12	Sweden	13	Japan	16	Brazil	18
				USA	11	China	15	Sweden	18

2015, Piracicaba		2018, Bonn		2023, Beijing	
Brazil	81	Germany	63	China	108
China	31	Brazil	40	Brazil	44
Germany	25	USA	33	Germany	23
USA	22	China	23	USA	14