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Photosynthesis and Respiration in Conifers A Classified Reference List 1891—1977

Fotosyntes och respiration hos barrträd Sammanställning av litteratur 1891—1977

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Abstract

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The bibliography contains 410 papers on photosynthesis, respiration or both, for 85 different coniferous species. Only papers written—or with abstract and figure legends—in English, French, German or one of the Scandinavian languages are included. To facilitate the finding of relevant information each paper has been classified according to its content and this information has been compiled into tables. The tables show which processes other than photosynthesis and/or respiration were studied, and which factors were studied in relation to the exchange of carbon dioxide. The tables are arranged in alphabetic order according to the scientific names of the different species.

> *Research is to see what everybody*
> *else has seen, and to think what*
> *nobody else has thought.*
>
> *Albert Szent-Gyorgyi*

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Contents

1 Introduction

Thomas Edison once said: "I start where the last man left off". This statement can be true only if one is aware of what has already been done within one's special field of interest. However, during recent decades, the flow of scientific papers has increased exponentially, and in consequence of this, it is today "normal" not to cite papers more than ten years old. If a "classical" work is found among the references, the impression often is that the author has never read that paper, but has inherited it from another author. This development is both sad and dangerous, and one should be aware of the fact that many of the investigations that are performed and published today had already been carried out decades ago. Of course, the instruments and the methods have improved over the years, but the results and their interpretation are often still the same. Much effort could be saved if only research workers would spend more time in the libraries trying to find out what has already been done.

With the increase in the number of papers published within different fields, there is an increasing demand for review articles and bibliographies which make it possible to follow related subjects or to acquire, within a reasonable length of time, knowledge within a new field of interest. This problem has become pronounced over the past few years, with the introduction of systems analysis and modelling in biology. Many scientists are now working with biological problems without having had a basic training in biology. These people need both an introduction to biological problems and guidance in finding relevant information for their models.

The present paper is an attempt to compile information available on photosynthesis and respiration of conifers and to classify the information from the papers in such a way that the relevant papers will be "easy" to find.

2 Materials and methods

2.1 Criteria for the selection of papers

Only papers including direct measurements of photosynthesis, respiration or both are included in the bibliography. Therefore, a number of papers which include the words "photosynthesis" or "respiration" in the title have been excluded, since the measurements actually consisted of gravimetric determination of changes in dry weight.

This report covers literature published in English, French, German or the Scandinavian languages only. An exception has been made to this when a paper contained an abstract and figure legends in one of the above languages.

The availability of papers from Swedish libraries has been a general criterion for the selection of papers. This means that most unpublished theses are not included in the bibliography, even if their subject was relevant.

2.2 How the papers were found

The search for relevant papers started with the author's own collection of reprints within the field, plus the reference lists from a large number of review articles on tree physiology and photosynthesis. The search was continued by way of the reference lists of all relevant papers found. Most of the relevant papers should have been found sooner or later by this method. To ensure that none were missed, the last fifteen years' issues of Forestry Abstracts, and all the bibliographies published on photosynthesis in the journal Photosynthetica (Academia Praha) were examined. No new papers appearing after the end of June 1978 were included, which means that a number of reports dated 1977 had not appeared at that time and are therefore excluded.

2.3 Classification of the papers

Since one of the objectives of the bibliography is to facilitate the finding of papers concerned with different aspects of the carbon dioxide exchange of coniferous species, a classification key was worked out. The result of the classification was tabulated, each paper being classified according to its content. The object of the classification was not to indicate whether a paper is good or bad—that is for the reader to judge—but to indicate concisely the content of each paper.

2.4 How to read the tables

The tables are divided into nine different main entries; Species, Stage, Organ, Processes, Abiotic (factors), Biotic (factors), Time (span), Season and Place. Each of these titles is then divided into a number of subtitles, making a total of 33 different entries. In spite of the many key-words, it was not possible to cover all the different features found in the reports. Some simplifications was necessary, this took form of combining different subjects under the same key-word. To facilitate the use of the tables, some guidance will be given below.

Species: The tables are arranged in alphabetic order, according to the scientific name of the species. The English name is found within brackets. The scientific and English names are in most cases according to "A Field Guide to the Trees of Britain and Northern Europe" (Mitchell 1974).

If the common English name of the species only is known to the reader, he can find his way in the tables by using an English index in the Appendix.

Stage: Here it is shown whether the measurements were performed on trees, seedlings or both. "Seedling" is not clearly defined, but in most cases the definition from the paper in question has been used.

Organ: Here it is shown which organ(s) of the plant was used for the measurements, and whether the organ was attached or detached. If the shoot of a tree or a seedling was used, it is indicated only whether or not the shoot was attached. It should be noted that in some investigations, different organs may have been used, which may cause some confusion. For example, an attached shoot and a detached root may have been used, and it is then not possible to decide from the table which organ was attached.

Processes: Either photosynthesis or respiration must have been studied if a paper is found in the tables. Therefore, one or both of these processes will always be marked. If other processes were studied as well, this may be discovered under the relevant subtitle.

Abiotic (factors): When the effect of an abiotic factor upon the carbon dioxide exchange has been studied, this may be found under this main title. However, if a diurnal pattern of CO_2-exchange is reported, together with simultaneous records of temperature and irradiance, nothing will be marked under the key-words irradiance and temperature. If the same data set was used to plot a dose-response curve for CO_2-exchange against irradiance, temperature or both, marks will be found under the relevant subtitles.

Under the different subtitles Abiotic (factors) the following can be found:

Irradiance: Includes both quantity and quality of light.

Temperature: Includes both air- and soil temperature.

Water: Covers different aspects of water supply, induced water stress or both.

Chemicals: Includes biocides, antitranspirents, hormones, etc.

Pollution: Includes all air-borne pollutants.

Biotic (factors): Marks under this title do not necessarily mean that dose-response curves have been established between CO_2-exchange and the marked factor.

Chlorophylls: A mark under this subtitle shows that figures for the chlorophyll content of the organ studied can be found in the paper.

Age: May be the age of the plant material or the organs used in the investigation. A mark means that more than one age has been studied.

Provenances: Includes different genetic aspects such as provenance, crossings, clones, etc.

Time: Gives the time span of the study.

Season: Gives the season when the study was performed.

Place: Studies where the plant material was brought from the field into the laboratory are classified as laboratory studies. The same is true for measurements in greenhouses, even if no artificial light was used.

Often some basic information is lacking in the tables, such as stage of plant material or whether the measurements were made on attached shoots or not. When information such as this is missing, it is due to incomplete description of the experiments in the original paper.

3 Results and discussion

In total, 410 relevant papers were found, a figure that could probably have been improved by a few per cent by continued search in the library. The reports cover 85 different coniferous species, which means that many of the important timber-producing conifers of the world have not been subject to investigations of their gas exchange.

More than 75 per cent of the reports were published after 1960, and the tendency is that the publishing rate is still increasing (cf. Figure 1). Even if the number of papers published over the years follows an exponential curve ($r^2 = 0.95$) some variation can be found from year to year (cf. Figure 2). The "breakthrough" in gas exchange studies came with the development of infra-red gas analysis (IRGA), which permitted continuous and accurate measurement of carbon dioxide fluxes. The first paper published in plant physiology using this technique came in 1949, after which there was a steady increase in the number of papers published on photosynthesis and respiration until the end of the 1960s. After 1968, the year with the highest number of published reports, there was a

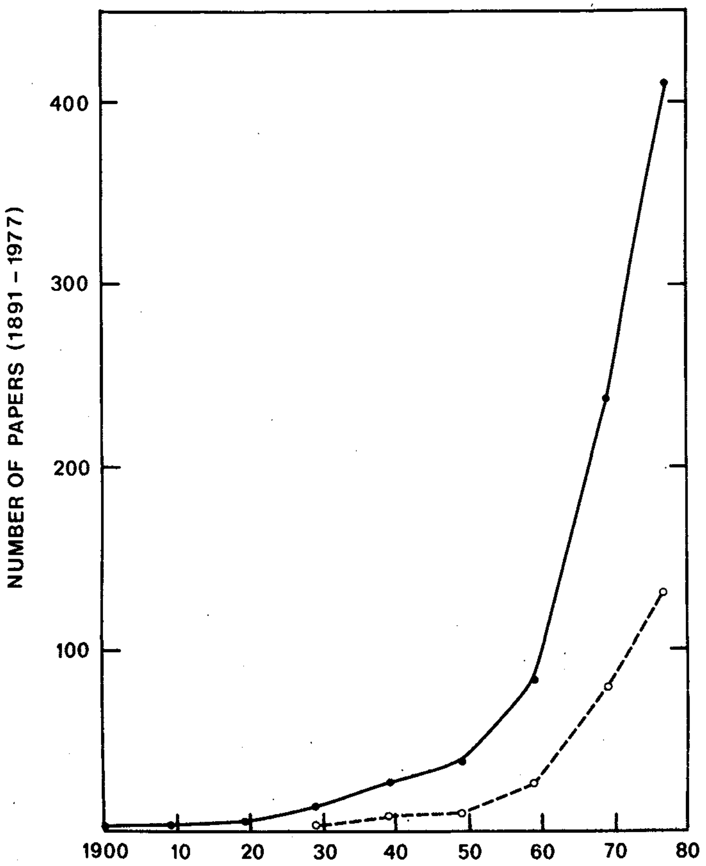

Figure 1. The cumulative number of papers published on carbon dioxide exchange in conifers, 1891—1977.
Solid line: Total number of papers. Broken line: Number of published field studies.

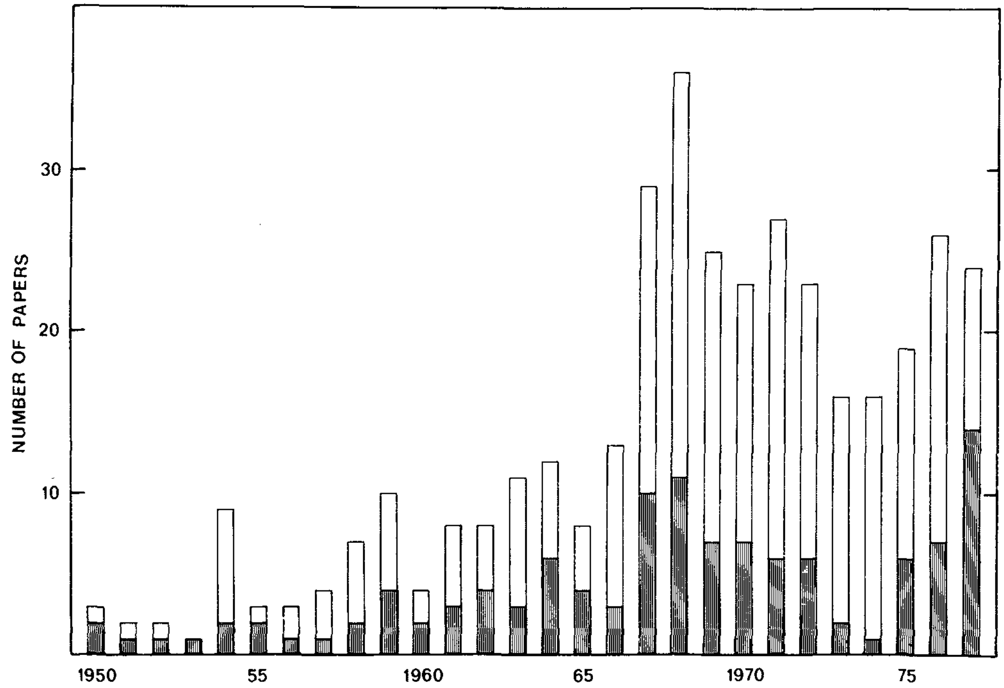

Figure 2. Diagram showing the yearly number of reports published on carbon dioxide exchange in conifers, 1950—1977. Laboratory studies: open part of bar, Field studies: Shaded part of bar.

decrease for six years, but in the last years of the period the trend has been upward. Reasons for the decline are not easy to find, although one could be that during this time many laboratories turned to studies of C-4 plants and photorespiration, and that in the case of photorespiration they often preferred to work with "easier" plant material than conifers.

Field studies of gas exchange make up 25 per cent only of the total number of reports (cf. Figures 1 and 2). However, for field studies the highest figure was found in 1977, which points to the fact that ecophysiological field studies have entered a "new era". This is due partly to the development of new techniques and methods which facilitate work under field conditions, and partly a shift in research policy, towards an emphasis on the functioning of ecosystems and applied questions (e.g. IBP — International Biological Programme and MAB — Man and Biosphere).

The distribution of papers between different species is very uneven (Figure 3, Tables 1—18). Scots pine *(Pinus silvestris)* and Norway spruce *(Picea abies)* are the most popular species, with more than one hundred papers published per species. There are then only 14 further species with ten published reports or more (Figure 3). Especially discouraging are the figures of field studies of trees under "natural" environmental conditions. Most of the 410 papers deal with seedlings, which means that many of the critical ecophysiological features of a species cannot be revealed at this early stage of development.

Less than 25 per cent of the papers contain information on the water balance of the studied plant material, and for some species the figures are even lower (cf. Figure 3). Thus the main information found in the reports concerns the performance of net carbon dioxide exchange under more or less well defined environmental conditions.

When one is trying to analyze the response-patterns of CO_2-exchange in relation

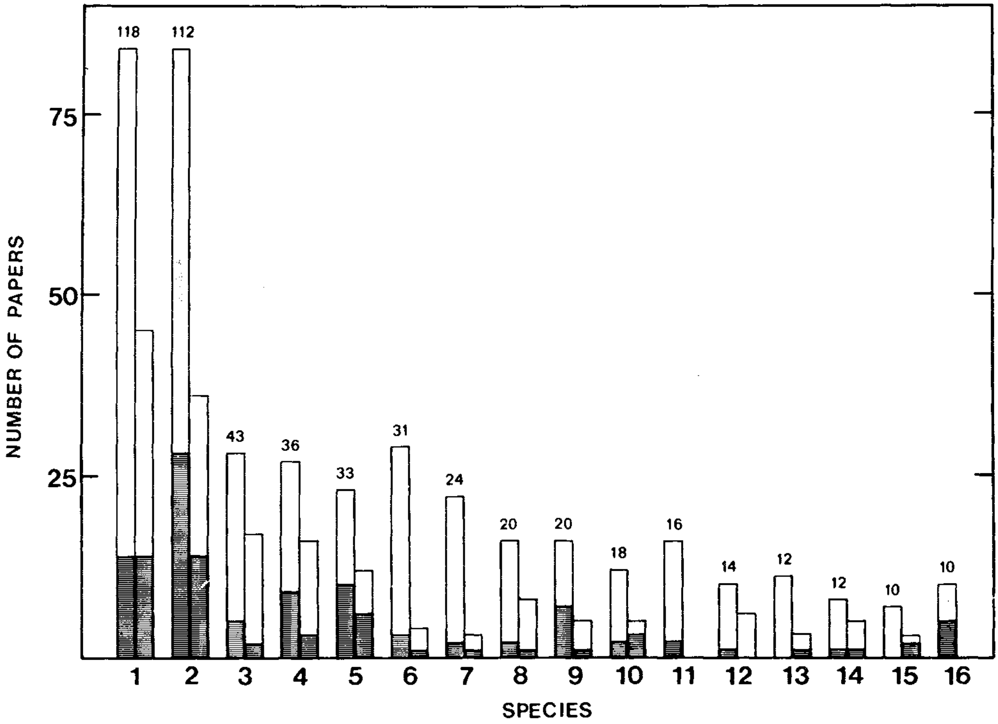

Figure 3. Diagram showing the number of reports published on carbon dioxide exchange for different coniferous species. Left bar: Laboratory studies. Right bar: Field studies. Shaded part of the bars: Number of reports where transpiration studies were included. The figure above each pair of bars gives the total number of reports.

Species: 1. Pinus silvestris, 2. Picea abies, 3. Pseudotsuga menziesii, 4. Pinus cembra, 5. Larix decidua, 6. Pinus strobus, 7. Pinus taeda, 8. Cryptomeria japonica, 9. Picea sitchensis, 10. Abies alba, 11. Pinus resinosa, 12. Pinus densiflora, 13. Pinus pondorosa, 14. Pinus nigra, 15. Pinus contorta, 16. Pinus radiata.

to different environmental factors, information about the water relations of the plant—especially transpiration—is often needed. Without this information, it is frequently not possible to tell whether the reported effects or patterns were due to processes directly involved in the fixation and(or) release of carbon dioxide, or whether they were merely an indirect effect caused by changes in stomatal conductance caused by changes in water balance.

The majority of papers are on photosynthesis, and only a small fraction deals with the respiration of non-green parts of the biomass. For the understanding of the control of primary production it is obvious that respiratory losses must also be taken into account. Information from *in situ* measurements of stem- and root-respiration is especially necessary, to make it possible to understand and to calculate the carbon balance and its control at the individual or stand level.

4 Acknowledgements

This report would never have been published without skilful and patient assistance from Miss E. Arwidsson to whom I wish to express my sincere thanks. I am also indebted to the helpful librarians at the "Forestry Library" in Stockholm. Thanks are also due to Miss A-M. Eriksson and Mr. Z. Pollak for typing the reference lists.

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5 Sammanfattning

I den allt stridare strömmen av vetenskapliga rapporter ökar behovet av litteratursammanställningar och översiktsartiklar. Detta har blivit speciellt accentuerat under de senaste åren då en ny kategori "biologer" kommit att arbeta med modellering av biologiska system. Dessa modellerare saknar ofta en biologisk grundutbildning och har därför av naturliga skäl stora initialsvårigheter då det gäller att tränga in i olika biologiska problemområden eller att finna relevant information som går att utnyttja vid modelleringen.

Den föreliggande rapporten är en sammanställning av den litteratur som publicerats rörande barrträds fotosyntes och respiration från 1891—1977. Sammanställningen omfattar 410 uppsatser och berör 85 olika barrträdsarter. För att förenkla sökandet av relevant information har varje uppsats klassificerats avseende dess innehåll. Denna information finns sammanställd i tabellform och tabellerna har ordnats i alfabetisk ordning efter arternas latinska namn.

Vid genomläsningen och klassificeringen av de ingående arbetena var det slående hur tendensen är allt klarare att man inte längre "orkar" läsa uppsatser som är äldre än tio år. Detta medför att man ofta genomför undersökningar ovetande om att samma undersökningar i princip genomfördes och publicerades för tiotals år sedan. Denna utveckling är givetvis både sorglig och farlig för det verkar som om man glömt att även om man tidigare ej hade tillgång till dagens sofistikerade apparatur så fanns det många skickliga forskare som från sina "primitiva" undersökningar drog samma slutsatser som dagens "datoriserade" forskare. Mycken möda och stora resurser kunde användas effektivare ifall forskaren av idag ägnade lite mer tid åt att penetrera redan publicerade arbeten.

Trots det relativt stora antalet uppsatser inom ämnet så är det endast 16 arter som varit föremål för tio eller fler publicerade undersökningar rörande fotosyntes och/eller respiration. Detta innebär att många av världens viktiga virkesproducerande arters grundläggande biologi fortfarande är höljd i dunkel. Likaså är det endast ett litet antal av de publicerade undersökningarna som utförts på intakta träd i sin "naturliga" miljö. Huvuddelen av undersökningarna har utförts på plantmaterial, vilket innebär att resultaten ofta är svåra att generalisera till att gälla även för äldre träd.

6 Tables

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
ABIES ALBA (COMMON SILVER FIR)		×					×		×	×						×												×		×	×		12
		×					×		×	×						×												×		×	×		13
		×		×			×			×		×				×										×	×	×	×		×		73
		×		×			×			×																					×		74
		×		×			×			×		×	×					×								×		×	×		×		75
		×					×		×	×						×									×					×		×	121
		×					×		×			×						×														×	126
	×	×					×	×	×	×											×				×						×		135
	×							×	×			×																				×	140
		×					×		×	×							×														×		143
	×						×		×	×					×	×							×		×					×		×	195
	×						×		×			×			×			×						×							×		228
	×							×	×						×											×	×			×	×		244
	×							×	×	×						×										×	×		×	×	×		252
	×							×		×																×		×		×	×		254
	×							×	×	×						×															×		255
	×							×	×							×												×		×		×	256
		×		×			×		×	×						×															×		277

ABIES AMABILIS		X			X		X	X	X					X								X		108
(RED FIR)		X			X		X	X	X					X								X		274
ABIES BALSAMEA	X	X			X	X	X	X			X	X		X	X		X		X	X		X	X	57
(BALSAM FIR)		X			X		X				X	X	X									X		85
		X			X		X		X								X	X	X				X	179
		X			X		X		X										X			X		180
	X					X	X	X		X					X		X	X	X			X		181
		X			X		X	X	X					X								X		274
ABIES CONCOLOR	X					X	X						X									X		68
(COLORADO WHITE FIR)		X		X		X	X								X							X		82
	X	X			X	X	X					X	X									X		379
ABIES FIRMA		X		X		X		X														X		237
(MOMI FIR)																								
ABIES GRANDIS		X	X		X			X	X	X	X			X			X		X	X		X		75
(GIANT FIR)	X					X	X								X		X	X	X	X	X	X		84
		X			X		X	X						X		X			X				X	109
		X			X		X	X			X	X							X				X	110
		X			X		X	X	X					X								X		274
ABIES LASIOCARPA		X			X		X	X	X					X								X		274
(ALPINE FIR)																								

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
ABIES MARIESII (MARIES'S FIR)	X		X	X				X	X	X					X	X			X				X								X		158
ABIES PROCERA (NOBLE FIR)		X		X			X			X		X	X		X			X								X		X	X		X		75
		X					X		X												X							X			X		77
		X					X		X	X		X						X													X		108
		X					X		X	X								X							X			X				X	109
		X					X		X	X					X	X												X				X	110
ABIES SAKHALINENSIS (SAKHALIN FIR)	X		X	X				X		X						X															X		139
	X		X	X				X		X																						X	381
ABIES VEITCHII (VEITCH'S SILVER FIR)	X		X	X			X		X	X					X	X			X				X								X		158
CALOCEDRUS DECURRENS (INCENSE CEDAR)		X			X		X		X												X							X			X		77
	X	X					X	X	X							X	X														X		379

CHAMAECYPARIS		X			X		X		X												X							X			X		77
LAWSONIANA																																	
(LAWSON CYPRESS)																																	
CHAMAECYPARIS	X							X	X						X											X	X			X	X		244
NOOTKATENSIS																																	
(NOOTKA CYPRESS)																																	
CHAMAECYPARIS OBTUSA	X							X	X	X					X										X	X					X		99
(HINOKI CYPRESS)	X		X					X		X																					X		107
		X		X			X	X	X	X			X		X	X		X							X	X	X	X	X	X	X	X	203
		X		X			X	X	X	X			X		X	X		X							X	X	X	X	X	X	X	X	206
		X					X		X	X						X										X		X		X			212
		X	X		X			X		X																					X		237
		X	X		X			X		X													X									X	239
	X	X					X		X	X			X		X							X	X		X			X	X		X	X	322
CHAMAECYPARIS PISIFERA	X							X	X	X					X	X										X	X	X	X	X	X		229
(SAWARA CYPRESS)	X						X		X			X														X	X		X	X		X	242
CRYPTOMERIA JAPONICA	X							X	X	X					X										X	X					X		99
(JAPANESE RED CEDAR)	X		X					X		X																					X		107
	X				X			X		X									X												X		120
		X	X				X		X	X		X						X													X		201
		X		X			X	X	X	X			X		X	X		X							X	X	X	X	X	X	X	X	203
		X					X	X	X	X			X		X	X		X								X	X	X	X	X	X	X	206
		X					X		X	X					X			X													X		208
		X					X		X	X					X			X													X		209
		X					X	X	X	X					X										X	X		X	X		X	X	211
		X					X		X	X						X										X		X		X	X		212

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
CRYPTOMERIA JAPONICA (JAPANESE RED CEDAR)	X						X		X	X					X	X								X	X		X					X	213
	X		X							X			X													X	X	X	X	X		X	236
		X	X	X			X	X		X																					X		237
	X		X		X			X		X																					X		238
	X		X					X		X																						X	239
	X				X			X	X						X		X					X				X			X	X	X		317
	X				X			X	X														X			X		X	X		X		318
	X	X					X		X	X		X			X							X	X		X			X	X		X	X	322
	X			X				X		X																X		X		X	X		340
	X			X	X			X		X																						X	381
JUNIPERUS COMMUNIS (COMMON JUNIPER)	X						X		X	X		X						X														X	267
	X		X					X		X						X														X	X		273
	X						X		X	X					X	X									X	X	X		X	X		X	345
		X					X		X	X					X																X		406
JUNIPERUS DEPPEANA		X					X		X								X	X													X		36
		X					X			X	X						X	X													X		37

JUNIPERUS OSTEOSPERMA		X					X		X	X						X																X	198
JUNIPERUS SABINA	X				X			X	X							X															X		78
(SAVIN)																																	
JUNIPERUS VIRGINIANA	X							X	X								X														X		68
(PENCIL CEDAR)	X		X					X		X						X										X	X	X	X	X	X		243
LARIX DECIDUA	X						X		X	X		X																	X			X	16
(EUROPEAN LARCH)	X							X	X								X														X		68
		X		X			X			X		X				X										X	X	X	X		X		73
		X		X			X			X																					X		74
		X		X			X			X		X	X		X			X								X		X	X		X		75
	X	X							X			X									X										X	X	96
		X					X		X			X				X															X		101
	X		X				X			X																X		X	X			X	117
		X		X				X		X						X								X		X		X	X		X		123
		X					X		X										X												X		131
		X	X				X		X	X					X															X	X		132
		X	X	X			X			X		X			X							X					X			X	X		134
		X					X		X	X			X			X										X	X	X	X	X	X		165
	X						X		X			X			X	X									X			X				X	218
	X						X		X			X												X								X	222
		X					X		X			X							X												X		226
	X							X	X							X												X		X		X	254
	X				X			X	X	X						X															X		255
	X				X			X	X							X												X		X		X	256
	X							X	X	X		X			X	X									X			X	X			X	262

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
LARIX DECIDUA (EUROPEAN LARCH)		X					X		X			X			X			X													X		264
	X							X	X						X			X						X	X			X	X		X	X	266
	X		X					X		X						X														X	X		273
		X					X		X			X								X											X		275
		X					X		X	X																X	X	X	X			X	329
		X					X		X	X								X													X		332
	X						X		X																				X			X	333
		X					X		X			X						X													X		334
		X					X		X			X																			X		335
	X							X		X						X													X		X		338
		X					X		X												X										X		351
		X					X	X	X			X									X											X	352
	X		X					X		X																					X		405
LARIX KAEMPFERI (JAPANESE LARCH)	X			X				X		X																					X		51
		X		X			X			X		X	X		X											X		X	X		X		75
		X						X	X				X		X		X					X									X		83
	X							X	X																	X	X	X	X	X	X		84
	X		X				X			X						X							X			X		X	X			X	117
		X					X		X	X			X													X	X	X	X	X	X		165

		X			X		X	X						X												X		220
	X				X		X		X									X									X	221
	X				X		X				X		X						X		X		X	X		X	X	266
Larix laricina (Tamarack)	X					X	X					X														X		68
	X					X	X											X				X				X		78
	X					X	X				X															X		308
Larix sibirica (Siberian larch)		X			X		X	X		X											X	X	X	X	X	X		165
Metasequoia glyptostroboides (Dawn redwood)	X			X		X		X						X												X		120
		X	X			X		X						X												X		146
		X			X		X	X	X				X				X			X			X			X		366
Picea abies (Norway spruce)		X			X		X		X							X										X		4
		X			X		X	X	X								X		X							X		15
	X				X	X	X	X													X	X	X	X	X	X		23
		X			X		X	X					X													X		39
		X			X		X				X															X		40
		X			X		X				X															X		41
		X			X		X				X															X		42
		X			X		X				X															X		44
		X			X		X				X															X		45
	X				X		X								X									X			X	46
		X			X		X	X	X							X					X	X			X	X	X	47
	X				X		X		X							X								X			X	49

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
PICEA ABIES (NORWAY SPRUCE)		X					X		X	X		X				X															X		50
	X			X				X		X																					X		51
	X							X	X																						X		56
	X							X		X						X															X		61
	X							X	X								X														X		68
		X		X			X			X						X										X	X	X	X		X		73
		X		X			X			X																					X		74
		X		X			X			X		X	X		X			X								X		X	X		X		75
		X					X		X												X							X			X		77
	X						X		X	X					X	X							X			X	X	X	X			X	86
	X		X				X			X		X													X	X	X	X	X			X	89
		X					X		X			X					X	X	X					X							X		95
	X	X							X			X									X		X								X	X	96
		X					X		X			X				X															X		101
		X		X				X		X			X					X													X		115
									X									X													X		116
	X		X							X						X										X		X	X			X	117
	X						X		X									X										X				X	118
		X					X	X	X						X																X		119
		X					X		X	X						X						X								X		X	121
		X					X		X	X		X								X											X		122

		x		x					x					x							x		x		x	x		x		123
		x				x	x	x	x	x			x															x		124
		x				x		x	x				x				x											x		125
		x				x		x		x						x												x		126
		x				x		x	x				x				x		x									x		128
		x		x		x	x	x	x	x			x				x											x		129
		x				x		x	x								x											x		131
		x				x		x										x					x		x	x		x	x	133
	x	x				x	x	x	x									x				x						x		135
		x		x		x	x	x	x				x				x		x									x		137
	x						x	x		x												x							x	140
		x				x		x	x	x					x													x		143
		x				x		x	x	x			x	x														x		144
	x	x					x	x	x	x			x				x		x										x	157
		x				x		x	x	x			x	x	x	x												x		173
		x		x			x		x					x						x			x		x	x		x		189
	x					x		x	x											x		x				x			x	195
	x		x				x		x					x									x	x	x	x	x	x		200
	x		x				x		x					x						x					x	x		x		202
	x					x		x		x			x	x		x						x							x	216
		x				x		x	x		x									x			x	x	x				x	217
	x					x		x		x												x			x	x			x	219
		x				x		x	x	x							x											x		220
	x					x		x		x										x									x	221
	x					x		x		x										x									x	223
	x					x		x		x										x						x			x	224
		x					x	x		x											x							x	x	225
		x				x		x									x											x		226
	x					x		x					x			x				x	x	x			x				x	228
		x			x		x					x																x		231

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
PICEA ABIES (NORWAY SPRUCE)		X				X		X						X																	X		235
	X		X		X		X	X		X																X	X	X			X		240
	X						X		X	X																				X		X	241
	X							X	X						X											X	X			X	X		244
		X					X		X	X	X		X									X		X							X		246
	X							X		X														X				X		X	X		253
	X							X	X							X												X		X	X		254
	X				X			X	X	X						X															X		255
	X							X	X	X																		X		X		X	256
	X						X		X							X														X	X	X	257
	X							X		X						X															X		258
	X						X		X	X					X	X									X					X	X		259
	X							X	X	X						X										X	X	X	X	X	X		260
	X							X	X	X					X	X															X		261
	X							X	X	X		X			X	X									X			X	X			X	262
	X						X		X	X					X										X			X			X	X	263
		X					X		X			X			X			X													X		264
									X	X						X														X	X		272
		X					X		X			X								X											X		275
		X					X		X	X					X									X		X	X	X	X	X	X		287
	X							X	X	X																X	X		X	X		X	288

X			X			X		X										X			X		X		X	X		296
	X				X			X											X							X		297
X					X			X		X								X		X	X	X	X	X	X		X	300
X					X			X		X								X			X						X	301
							X	X										X								X		315
X							X	X		X		X	X				X	X					X				X	316
X						X	X	X				X					X						X				X	324
	X				X		X	X						X												X		332
	X				X		X		X					X												X		334
	X				X		X		X					X							X	X	X	X		X		337
X		X				X		X					X								X	X	X	X		X		338
X					X		X	X					X											X			X	342
X					X		X	X				X	X							X	X	X	X	X	X		X	345
	X				X		X	X								X										X		354
	X				X		X		X				X													X		356
	X					X	X		X							X										X		357
X						X	X	X					X												X	X	X	360
	X				X		X	X	X				X							X					X	X		367
	X				X		X	X	X				X	X											X	X		368
	X				X		X	X	X					X											X	X		369
	X				X		X	X	X				X						X						X	X		370
	X				X		X	X					X												X	X		382
	X				X		X					X														X		403
X						X	X	X													X				X	X	X	404
X		X				X		X																		X		405
	X	X			X	X	X	X				X	X								X	X	X	X	X	X		406
	X			X		X					X				X											X		410

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
PICEA ENGELMANNII		X					X		X						X																X		40
(ENGELMANN SPRUCE)		X					X		X	X					X			X													X	X	281
PICEA GLAUCA	X	X					X	X	X	X					X	X		X					X			X		X	X		X	X	57
(WHITE SPRUCE)	X						X		X			X									X				X				X			X	169
		X					X		X	X	X				X		X														X		268
		X						X	X	X	X						X														X		269
		X					X	X		X	X									X											X		270
	X							X	X	X																X	X	X	X	X	X		303
	X							X	X						X																X		308
PICEA GLEHNII	X		X	X				X		X						X															X		139
(SAKHALIN SPRUCE)	X		X	X				X		X													X									X	381
PICEA JEZOENSIS	X		X	X				X		X						X																X	139
(HONDO SPRUCE)	X		X	X				X		X																						X	381

PICEA MARIANA (BLACK SPRUCE)	X							X	X	X													X			X	X	X	X	X	X		58
		X					X		X	X																				X	X	X	31
	X							X	X						X																X		308
	X				X			X		X																					X		311
	X						X		X	X					X			X							X			X				X	359
PICEA OMORIKA (SERBIAN SPRUCE)		X					X		X	X		X									X										X		47
		X					X		X	X		X				X															X		50
		X					X		X	X		X						X												X	X		369
PICEA POLITA (TIGER TAIL SPRUCE)		X			X			X		X																					X		237
PICEA PUNGENS (COLORADO SPRUCE)	X							X	X	X																X	X	X	X	X	X		23
		X					X		X	X	X				X																X		59
	X							X	X								X														X		68
		X					X		X												X							X			X		77
		X			X			X	X														X								X		82
	X		X					X		X						X										X	X	X	X	X	X		243
PICEA SITCHENSIS (SITKA SPRUCE)		X				X	X	X	X			X						X													X		14
		X					X		X	X	X				X																X		59
		X					X		X	X	X	X			X		X														X		60
		X					X		X				X		X																X		67
		X		X						X		X	X		X			X								X		X	X		X		75
		X			X			X	X								X					X									X		83
	X							X	X																	X	X	X	X	X	X		84

		109	110	114	156	170	171	186	214	215	216	341	362	406			197	198	299			
Species		PICEA SITCHENSIS (SITKA SPRUCE)															PINUS ARISTATA (BRISTLE-CONE PINE)					
Stage	Trees			X				X		X	X		X						X			
	Seedlings	X	X		X	X	X	X	X	X	X	X		X			X	X				
Organ	Stem, branches																					
	Roots																					
	Needles																					
	Chloroplasts					X	X															
	Attached	X	X	X	X			X	X	X	X	X	X				X	X	X			
	Detached			X		X	X	X		X	X											
Processes	Photosynthesis	X	X	X	X			X	X	X	X	X	X	X			X	X	X			
	Respiration	X	X	X				X			X	X	X	X			X	X	X			
	Photorespiration							X														
	Transpiration							X		X	X	X					X					
	Growth																					
	Electron transfer					X	X															
Abiotic	Irradiance		X	X	X	X	X	X			X		X	X								
	Temperature		X					X	X	X	X	X					X	X				
	Carbon dioxide							X			X											
	Water	X										X										
	Mineral nutrients																					
	Chemicals																					
	Pollution																					
Biotic	Chlorophylls						X															
	Age												X									
	Provenances																					
Time	Diurnal variation	X		X									X				X					
	Seasonal variation										X						X		X			
Season	Spring										X								X			
	Summer	X	X	X							X		X				X					
	Autumn							X		X	X		X						X			
	Winter										X								X			
Place	Laboratory				X	X	X	X	X	X	X	X		X				X				
	Field	X	X	X						X			X				X	X	X			
No.	Reference	109	110	114	156	170	171	186	214	215	216	341	362	406			197	198	299			

PINUS ATTENUATA		X			X		X				X		X												X		35
(KNOBCONE PINE)		X			X		X	X					X	X											X		110
		X			X		X	X			X	X													X		376
	X				X		X												X			X	X	X		X	377
		X			X		X	X				X						X							X		378
	X	X			X	X	X					X	X												X		379
PINUS BANKSIANA		X	X			X		X																	X		163
(JACK PINE)		X					X			X							X	X		X		X	X		X		182
		X					X					X						X							X		183
		X				X	X									X	X		X						X		343
		X	X			X		X							X		X								X		358
PINUS BRUTIA		X			X		X	X	X					X											X		201
(CALABRIAN PINE)																											
PINUS CEMBRA	X	X			X		X													X	X		X	X	X		8
(SWISS STONE PINE)		X			X		X		X					X											X		52
		X			X		X		X					X						X		X		X	X		53
	X				X		X		X										X	X	X	X	X	X		X	55
		X	X					X				X								X		X	X		X		123
		X			X		X	X											X					X		X	127
		X			X		X																	X	X		132
		X			X		X		X							X								X	X		134
	X				X		X	X	X										X							X	142
		X			X		X		X										X			X			X	X	145
	X			X		X		X				X										X		X	X		253
	X			X		X	X					X										X		X		X	254

Species	No.	Place		Season				Time		Biotic			Abiotic							Processes						Organ						Stage	
	Reference	Laboratory	Field	Spring	Summer	Autumn	Winter	Diurnal variation	Seasonal variation	Chlorophylls	Age	Provenances	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Trees	Seedlings
PINUS CEMBRA (SWISS STONE PINE)	255	X												X						X	X							X			X	X	
	256		X		X		X							X						X											X	X	
	257	X	X				X							X						X											X	X	
	258	X												X							X										X	X	
	260	X	X	X	X	X	X		X					X						X	X										X	X	
	261	X											X	X						X	X										X	X	
	275	X																X		X			X							X			X
	302	X		X	X	X	X		X					X						X	X									X	X	X	X
	303	X		X	X	X	X		X											X	X										X	X	
	324	X	X			X		X					X	X						X	X									X			X
	325		X	X				X					X	X						X	X									X			X
	326	X		X		X			X				X	X						X	X									X			X
	327		X	X	X	X	X		X				X	X						X	X									X			X
	328	X	X	X	X	X	X		X					X						X	X						X			X			X
	329		X	X	X	X	X		X											X	X									X			X
	330		X	X	X	X	X	X	X					X						X	X									X			X
	331	X	X	X	X	X	X		X											X	X						X			X			X
	332	X														X				X	X									X			X
	334	X														X				X			X							X			X
	335	X																		X			X							X			X
	336	X	X	X		X	X		X					X						X											X	X	

		X					X		X			X				X					X						X	X	X	X		X		337
	X		X					X		X						X										X	X	X	X		X		338
		X					X		X													X	X		X						X		343
PINUS CLAUSA		X					X		X	X						X															X		251
(SAND PINE)																																	
PINUS CONTORTA	X						X		X	X		X													X				X			X	16
(LODGEPOLE PINE)		X					X		X				X		X																X		70
		X					X		X						X	X		X													X		71
	X						X		X			X									X				X				X			X	169
		X					X		X									X								X					X		199
		X					X		X						X																	X	281
	X							X	X	X																X	X	X	X	X	X		303
		X					X		X	X						X															X		304
		X					X		X	X			X		X									X							X		320
	X	X					X	X	X							X	X														X		379
PINUS COULTERI		X					X		X						X		X														X		35
(BIG-CONE PINE)		X					X		X	X							X	X													X		110
		X					X		X	X					X	X															X		376
	X						X		X																X			X	X	X		X	377
	X	X					X	X	X							X	X														X		379
PINUS DENSIFLORA	X		X		X			X		X						X			X				X			X	X	X	X	X	X		120
(JAPANESE RED PINE)		X		X			X	X	X	X			X		X	X		X							X	X	X	X	X	X	X	X	203
	X		X					X		X													X			X	X	X	X		X		204

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
Pinus densiflora (Japanese red pine)	X		X				X	X		X						X									X		X	X	X	X		X	205
		X		X			X		X	X			X		X	X		X								X	X	X	X	X	X	X	206
		X					X		X	X			X					X													X		207
		X					X		X	X					X			X													X		208
		X					X		X	X					X			X													X		209
		X					X		X			X													X						X		210
		X					X		X	X						X										X		X		X	X		212
	X		X					X		X			X													X	X	X	X	X		X	236
		X	X		X			X		X																					X		237
	X		X					X		X																						X	239
	X		X	X				X		X													X									X	381
Pinus echinata (Shortleaf pine)		X		X				X		X						X															X		2
		X		X				X		X																					X		286
Pinus elliotii (Slash pine)		X					X		X	X											X										X		10
		X					X		X	X					X					X			X								X		26
		X					X		X	X														X							X		38
		X	X				X		X	X																					X		98

	X		X				X											X	X	X	X	X		X	236
		X		X		X							X										X		276
		X		X		X									X	X							X		380
		X		X		X	X					X											X		401
PINUS FLEXILIS		X		X		X	X				X													X	198
(LIMBER PINE)																									
PINUS GRIFFITHII		X		X		X								X	X		X						X		343
(BHUTAN PINE)																									
PINUS HALEPENSIS		X		X		X	X		X	X	X	X											X		371
(ALEPPO PINE)		X		X		X			X		X	X											X		372
PINUS JEFFREYI	X	X		X	X	X					X	X											X		379
(JEFFREY´S PINE)																									
PINUS LAMBERTIANA		X		X		X	X			X	X												X		376
(SUGAR PINE)	X			X		X											X			X	X	X		X	377
	X	X		X	X	X					X	X											X		379
PINUS MERKUSII		X		X		X	X	X			X					X							X		188
(MERKUS PINE)																									
PINUS MONOPHYLLA		X		X		X	X				X												X	X	198
(SINGLELEAF PINE)																									

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
PINUS MONTANA	X							X	X							X														X	X		78
(MOUNTAIN PINE)		X					X		X			X										X								X	X		134
	X						X		X			X						X						X				X				X	288
	X							X		X						X												X		X	X		253
		X					X		X													X	X		X						X		343
PINUS MONTICOLA		X					X		X	X			X		X	X	X							X							X		323
(WESTERN WHITE PINE)																																	
PINUS MUGO		X					X		X	X		X	X									X		X							X		15
(DWARF MOUNTAIN PINE)	X						X		X	X		X													X				X			X	16
		X		X						X						X								X		X		X	X		X		123
		X					X		X	X					X				X													X	128
		X					X		X																					X	X		132
		X					X	X	X												X										X		354
PINUS NIGRA	X							X	X							X	X														X		68
(AUSTRIAN BLACK PINE)		X					X		X				X		X																X		70
	X							X	X	X					X		X					X	X			X	X	X	X	X	X		76

		X				X		X								X							X			X		77
		X				X		X	X																X	X	X	81
		X		X			X	X										X								X		82
		X				X		X	X										X							X		88
		X				X		X								X								X		X	X	133
	X		X	X			X		X												X	X	X			X		240
	X					X		X	X	X				X													X	267
		X				X		X							X											X		306
		X				X		X									X	X		X						X		343
Pinus palustris		X				X		X		X											X	X		X	X		X	242
(Longleaf pine)																												
Pinus peuce	X					X		X		X				X					X				X				X	228
(Macedonian pine)		X				X		X									X	X		X						X		343
Pinus pinaster		X				X		X									X	X		X						X		343
(Maritime pine)																												
Pinus pinea	X					X		X								X				X			X				X	6
(Italian stone pine)		X		X			X	X				X														X		79
		X				X		X	X	X				X												X		201
		X			X		X				X															X		386
Pinus pondorosa	X			X			X	X		X		X						X									X	17
(Western yellow pine)		X				X		X		X			X	X												X		36
		X		X			X	X										X								X		82

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
PINUS PONDOROSA (WESTERN YELLOW PINE)	X						X		X								X				X				X			X	X			X	94
	X	X					X		X	X					X	X		X				X			X	X	X	X	X		X	X	97
	X	X					X		X	X													X									X	104
	X						X		X	X					X	X									X							X	105
		X					X		X												X										X		196
		X					X		X							X															X		248
		X					X		X							X															X		249
		X					X		X							X															X		250
		X					X		X													X	X		X						X		343
PINUS RADIATA (MONTEREY PINE)		X					X		X	X		X				X		X													X		7
		X					X		X				X		X																X		70
		X					X		X	X		X						X													X		201
		X					X		X	X					X	X															X		282
		X					X		X			X				X															X		283
	X						X		X	X		X	X					X							X						X		284
	X		X					X		X																X	X	X	X	X	X		305
		X					X		X				X		X																X		319
		X					X	X	X	X		X			X	X		X							X						X		374
	X	X					X	X	X							X	X														X		379

PINUS RESINOSA (RED PINE)		X			X		X	X			X						X									X		25
		X			X		X		X						X											X		62
		X			X		X		X					X	X											X		63
		X			X		X	X				X														X		64
	X		X		X	X	X	X																		X		69
		X			X		X	X		X								X			X	X	X			X		93
		X			X		X	X													X			X	X	X		150
		X			X		X	X		X				X												X		230
		X			X		X	X							X											X		289
		X			X		X								X											X		290
		X			X			X							X											X		291
		X			X			X							X											X		292
		X			X		X	X							X											X		293
		X			X		X	X		X					X											X		294
		X			X		X			X					X											X		295
		X		X		X		X							X											X		358
PINUS RIGIDA (NORTHERN PITCH PINE)	X				X		X	X		X											X		X	X			X	22
	X				X		X	X												X	X	X		X	X		X	27
		X			X		X		X				X	X												X		36
		X	X		X		X	X			X															X		98
		X			X		X				X	X						X	X							X		156
		X		X	X		X	X		X								X	X							X		157
PINUS SEROTINA (POND PINE)		X			X		X	X								X										X		10

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
PINUS SILVESTRIS (SCOTS PINE)		x						x	x	x			x									x		x							x		3
		x					x		x						x						x										x		5
	x							x	x	x																	x				x		23
		x					x		x	x								x													x		39
		x					x		x	x		x									x					x	x	x		x	x	x	47
	x						x		x												x			x					x			x	48
	x			x				x		x																					x		51
		x					x		x						x																x		66
		x					x		x				x		x																x		67
	x							x	x								x														x		68
		x					x		x	x			x						x					x							x		72
		x		x			x			x		x				x								x		x	x	x	x		x		73
		x		x			x			x														x							x		74
		x		x			x			x		x	x		x			x								x		x	x		x		75
		x					x		x												x							x			x		77
		x					x		x			x	x		x						x										x		80
		x					x		x	x																				x	x		81
		x			x			x	x														x								x		82
		x					x		x	x					x									x							x		87
		x					x		x	x			x		x	x			x					x							x		90
		x					x		x	x					x									x							x		91

92		X							X							X	X	X					X	X		X					X		
96	X	X								X		X									X			X							X	X	
100	X				X												X	X					X	X		X						X	
109	X				X			X							X								X	X		X					X		
110	X				X												X	X					X	X		X					X		
112	X				X					X														X	X							X	
113	X	X	X	X																				X									
115		X													X								X		X				X		X		
117	X			X	X		X										X						X			X				X		X	
121	X		X					X									X						X	X		X					X		
123		X		X	X		X										X						X			X			X		X		
126	X														X						X			X		X					X		
130	X											X												X									
133	X	X		X								X												X		X					X		
135		X						X				X											X	X	X	X					X	X	
137		X												X				X					X	X		X			X		X		
141	X	X															X						X	X		X					X	X	
143		X														X							X	X		X					X		
161	X				X			X									X	X			X		X	X		X						X	
162	X		X	X	X	X	X	X		X							X	X					X	X		X						X	
172		X			X					X	X							X						X	X			X			X		
173		X													X	X	X	X			X		X	X		X					X		
174	X			X	X		X	X		X							X	X					X	X		X					X		
175	X				X									X			X	X					X	X		X						X	
176	X				X	X	X	X									X			X			X			X				X		X	
184		X					X							X	X					X			X	X	X			X			X		
185		X												X									X	X	X			X			X		
187		X							X											X			X	X		X					X		
189		X		X	X		X			X							X						X		X				X		X		
193	X																	X						X		X					X	X	

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
PINUS SILVESTRIS (SCOTS PINE)		×		×				×		×			×						×									×			×		194
		×					×		×	×			×										×			×	×	×				×	217
	×						×		×			×													×			×				×	218
		×					×		×	×		×							×												×		220
	×						×		×			×											×									×	221
	×						×		×			×											×									×	223
		×					×		×			×							×												×		226
	×						×		×	×		×	×													×						×	227
	×						×		×			×			×			×							×							×	228
		×				×		×						×																	×		238
	×		×		×			×		×																×	×	×			×		240
		×					×		×			×														×	×		×	×		×	242
	×							×	×						×											×	×			×	×		244
		×					×		×							×									×				×		×	×	245
		×					×		×			×				×									×					×	×		247
	×				×			×	×	×						×															×		255
	×							×	×							×												×		×	×		256
	×							×	×							×														×	×	×	257
	×							×	×	×		×			×	×									×			×	×			×	262
	×						×		×	×						×									×	×	×			×	×	×	265
		×					×		×	×	×							×													×		271

									×	×					×														×	×		272
		×					×		×	×			×										×							×	×	278
		×					×		×	×			×				×						×							×		298
	×	×					×	×		×					×										×	×	×	×		×	×	310
	×							×	×	×				×							×						×				×	314
	×							×	×	×				×	×							×								×		315
	×							×	×	×		×		×	×	×					×	×									×	316
		×						×	×			×					×		×						×	×	×	×		×		337
	×		×					×		×					×										×	×	×	×		×		338
	×						×		×	×												×			×	×	×	×	×		×	339
	×							×	×	×					×													×			×	342
		×						×	×												×	×		×						×		343
	×						×		×	×				×										×				×			×	344
	×						×		×	×				×	×									×	×	×	×	×	×		×	345
	×						×		×	×				×	×									×	×	×	×	×	×		×	346
		×					×		×	×									×												×	349
	×								×					×	×								×		×	×	×	×	×		×	350
	×							×	×			×								×						×		×			×	352
	×						×		×	×		×								×		×				×	×				×	353
	×							×	×			×																		×	×	355
		×					×		×			×			×															×		356
		×			×			×	×																					×		361
		×					×		×	×					×														×	×		382
		×					×		×	×			×					×			×									×		383
		×		×			×		×	×								×												×		384
		×			×			×	×	×								×			×									×		385
	×						×		×			×						×					×					×		×		389
		×					×		×	×	×			×		×														×		390
		×					×		×	×			×	×							×		×							×		391
		×					×		×	×			×																	×		392

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
PINUS SILVESTRIS (SCOTS PINE)		X					X		X	X														X		X	X	X	X	X	X		393
		X					X		X	X					X		X							X							X		394
		X					X		X	X												X		X							X		395
		X					X		X			X										X		X						X	X		396
	X				X			X	X											X			X			X	X	X	X	X	X		397
		X		X				X	X	X	X											X									X		398
		X					X		X	X					X							X			X			X			X		399
		X					X		X	X								X								X		X	X		X		400
		X					X		X	X														X		X		X	X		X		402
		X					X		X						X																X		403
	X		X					X		X																					X		405
		X	X					X	X	X					X	X										X	X	X	X	X	X		406
		X				X								X																	X		407
		X				X								X		X															X		408
		X				X								X																	X		409
		X				X								X																	X		410
PINUS STROBUS (EASTERN WHITE PINE)		X					X		X	X																					X		10
					X			X		X										X											X		11
		X					X		X												X										X		20

		X			X		X	X	X												X							X		24
		X					X	X	X			X																X		25
		X				X		X	X						X													X		39
		X				X		X				X																X		40
		X				X		X				X																X		41
		X				X		X				X																X		42
		X				X		X				X																X		43
		X				X		X				X																X		44
		X				X		X				X																X		45
	X						X	X						X														X		68
		X		X		X			X	X	X	X			X								X		X	X		X		75
		X			X		X	X											X									X		82
		X		X		X			X				X															X		123
		X				X		X										X								X		X	X	133
	X		X				X		X						X													X		149
		X		X		X		X	X	X					X				X				X		X	X		X		177
		X				X		X		X	X					X												X		178
		X				X		X	X		X												X	X	X	X	X	X		191
					X		X	X							X													X		192
	X					X		X	X			X										X			X			X	X	263
	X						X	X	X														X	X		X	X		X	288
		X		X		X			X		X												X	X	X	X	X	X		307
	X						X	X				X				X												X		308
		X				X		X											X	X		X						X		343
		X				X		X	X														X		X	X		X		347
		X				X		X	X			X																X		348
		X				X	X	X		X								X						X					X	352
		X		X			X		X								X											X		358

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
PINUS TAEDA (LOBLOLLY PINE)	X			X				X		X						X															X		9
		X					X		X	X											X										X		10
		X					X		X						X								X								X		18
		X					X		X						X																X		19
	X			X				X		X																	X				X		28
		X					X		X	X							X	X													X		29
		X							X	X														X							X		38
		X					X		X	X						X															X		64
		X					X		X						X		X														X		65
	X		X	X			X			X						X											X	X				X	138
		X					X		X			X	X		X																X		147
		X					X		X						X																X		148
		X					X		X	X																X			X	X	X		150
		X			X		X		X	X					X																X		151
		X					X		X	X					X																X		152
		X		X				X		X										X											X		153
		X					X		X	X														X							X		168
									X	X			X		X									X							X		190
		X					X		X	X			X									X				X	X	X	X	X	X		191
	X							X	X														X								X		276
		X					X		X	X														X							X		279

		X				X		X			X									X									X		280
	X	X				X		X	X						X									X	X	X	X	X	X	X	312
	X					X		X	X		X			X	X		X							X	X	X	X	X		X	313
PINUS THUNBERGII					X		X						X																X		232
(JAPANESE BLACK PINE)					X		X						X																X		234
	X		X	X			X		X												X									X	381
PSEUDOTSUGA MENZIESII		X		X		X	X	X	X					X	X															X	30
(DOUGLAS FIR)		X				X		X	X	X				X	X	X													X		31
	X						X	X	X			X		X							X			X	X	X	X	X	X		32
	X						X	X				X				X	X	X						X					X	X	33
	X						X	X				X		X				X			X								X		34
		X				X		X	X		X				X														X		50
		X						X														X							X		54
		X				X		X	X	X				X															X		59
	X						X	X								X													X		68
		X		X		X			X						X									X	X	X	X		X		73
		X		X		X			X						X														X		74
		X		X		X			X		X	X		X			X							X		X	X		X		75
		X				X		X												X						X			X		77
	X					X		X	X									X					X	X	X	X	X	X		X	102
	X					X		X	X														X	X	X	X	X	X		X	103
		X				X		X	X								X						X			X				X	109
		X				X		X	X					X	X											X				X	110
		X				X		X	X						X								X					X		X	121
		X				X		X			X						X													X	126
								X											X											X	130

	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
Species	**Stage**		**Organ**						**Processes**						**Abiotic**							**Biotic**			**Time**		**Season**				**Place**		**No.**
PSEUDOTSUGA MENZIESII (DOUGLAS FIR)		X					X		X												X								X		X	X	133
		X					X		X	X					X	X								X							X		155
		X					X		X						X																X		156
	X						X		X	X					X	X										X	X	X	X			X	159
	X						X		X	X			X		X	X							X			X	X	X	X				160
	X						X		X	X		X			X	X									X			X				X	161
	X						X		X	X					X	X							X		X	X	X	X	X	X		X	162
		X					X		X	X			X										X			X	X	X				X	217
	X		X					X		X																					X		240
		X					X		X							X															X		248
		X					X		X							X															X		249
	X							X	X	X		X			X	X									X			X	X			X	262
	X						X		X	X					X										X			X			X	X	263
		X					X		X						X							X									X		285
	X							X	X	X																X	X	X	X	X	X		303
		X					X		X							X							X	X							X		309
		X					X		X														X								X		363
		X							X														X								X		364
		X					X	X	X	X					X																X		365
		X					X		X	X		X				X								X						X	X		370
	X						X		X															X				X				X	375

		X			X		X	X	X				X			X					X		387
		X			X		X	X					X			X					X		388
SEQUOIA GIGANTEA	X					X	X			X							X	X		X	X		244
(BIG TREE)																							
TAXODIUM DISTICHUM	X					X	X					X									X		68
(BALD CYPRESS)	X		X					X														X	154
	X					X		X									X		X	X	X		253
TAXUS BACCATA	X			X		X	X				X									X	X		78
(COMMON YEW)	X					X	X			X							X		X	X	X		244
	X					X	X				X								X	X		X	254
	X			X		X	X	X			X										X		255
	X					X	X				X								X	X		X	256
	X					X	X				X									X	X	X	257
	X					X	X							X	X						X		373
TAXUS CUSPIDATA	X				X		X					X									X		68
(JAPANESE YEW)																							
THUJA OCCIDENTALIS	X			X	X		X				X									X	X		78
(WHITE CEDAR)		X				X	X				X										X		164
	X			X		X		X							X		X		X	X	X		296
	X					X	X			X											X		308

Species	Stage		Organ						Processes						Abiotic							Biotic			Time		Season				Place		No.
	Trees	Seedlings	Stem, branches	Roots	Needles	Chloroplasts	Attached	Detached	Photosynthesis	Respiration	Photorespiration	Transpiration	Growth	Electron transfer	Irradiance	Temperature	Carbon dioxide	Water	Mineral nutrients	Chemicals	Pollution	Chlorophylls	Age	Provenances	Diurnal variation	Seasonal variation	Spring	Summer	Autumn	Winter	Laboratory	Field	Reference
THUJA ORIENTALIS (CHINESE THUJA)	X				X			X	X							X														X	X		78
THUJA PLICATA (WESTERN RED CEDAR)		X		X			X			X		X	X		X			X								X		X	X		X		75
THUJA STANDISHII (JAPANESE THUJA)	X				X			X	X							X														X	X		78
THUJOPSIS DOLOBRATA (HIBA)	X		X					X		X																					X		107
TSUGA CANADENSIS (EASTERN HEMLOCK)		X					X		X						X	X												X			X		1
	X							X	X	X																X	X	X	X	X	X		23
		X					X		X	X					X																X		25
	X							X	X								X														X		68
							X		X						X																	X	107
	X							X	X						X											X	X			X	X		244
		X		X			X		X	X					X																X		321

TSUGA HETEROPHYLLA		X		X	X			X	X	X	X			X				X		X	X		X		75
(WESTERN HEMLOCK)	X					X	X											X	X	X	X	X	X		84
		X			X		X	X						X			X			X				X	109
		X			X		X	X			X	X								X				X	110
		X			X		X		X		X		X		X									X	136
		X			X		X				X												X		156
TSUGA SIEBOLDII	X		X		X			X		X								X	X	X	X	X		X	236
(JAPANESE HEMLOCK)																									

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8 Appendix

8.1 Scientific index

8.2 **English index**

8.3 Scientific and English names of species included

Abies alba (A. pectinata)	Common silver fir
Abies amabilis	Beautiful or Red fir
Abies balsamea	Balsam fir
Abies concolor	Colorado white fir
Abies firma	Momi fir
Abies grandis	Grand or Giant fir
Abies lasiocarpa	Alpine fir
Abies mariesii	Marie's fir
Abies procera	Noble fir
Abies veitchii	Veitch's fir
Calocedrus decurrens (Thuja gigantea)	Incense cedar
Chamaecyparis lawsoniana	Lawson cypress
Chamaecyparis nootkatensis	Nootka cypress
Chamaecyparis obtusa	Hinoki cypress
Chamaecyparis pisifera	Sawara cypress
Cryptomeria japonica	Japanese red cedar
Juniperus communis	Common juniper
Juniperus deppeana	
Juniperus osteospermum	
Juniperus sabina	Savin
Juniperus virginiana	Pencil cedar
Larix decidua (L. europea)	European larch
Larix kaempferi (L. leptolepis)	Japanese larch
Larix laricina	Tamarack
Larix sibirica	Siberian larch
Metasequoia glyptostroboides	Dawn redwood
Picea abies (P. exelsa)	Norway spruce
Picea engelmannii	Engelmann spruce
Picea glauca	White spruce
Picea glehnii	Sakhalin spruce
Picea jezoensis	Hondo spruce
Picea mariana (P. nigra)	Black spruce
Picea omorika	Serbian spruce
Picea polita	Tiger tail spruce
Picea pungens	Colorado spruce
Picea sitchensis	Sitka spruce
Pinus aristata	Bristle-cone pine
Pinus attenuata	Knobcone pine
Pinus banksiana	Jack pine
Pinus brutia	Calabrian pine
Pinus cembra	Swiss stone pine
Pinus clausa	Sand pine

Pinus contorta (P. murrayana)	Lodgepole pine
Pinus coulteri	Big-cone pine
Pinus densiflora	Japanese red pine
Pinus echinata	Shortleaf pine
Pinus elliotii	Slash pine
Pinus flexilis	Limber pine
Pinus griffithii	Bhutan pine
Pinus halepensis	Aleppo pine
Pinus jeffreyi	Jeffrey's pine
Pinus lambertiana	Sugar pine
Pinus merkusii	Merkus pine
Pinus montana	Mountain pine
Pinus monophylla	Singleleaf pine
Pinus monticola	Western white pine
Pinus mugo	Dwarf mountain pine
Pinus nigra (P. laricio)	Austrian black pine
Pinus palustris	Longleaf pine
Pinus peuce	Macedonian pine
Pinus pinaster	Maritime pine
Pinus pinea	Italian stone pine
Pinus pondorosa	Western yellow pine
Pinus radiata	Monterey pine
Pinus resinosa	Red pine
Pinus rigida	Northern pitch pine
Pinus serotina	Pond pine
Pinus silvestris	Scots pine
Pinus strobus	Eastern white pine or Weymouth pine
Pinus taeda	Loblolly pine
Pinus thunbergii	Japanese black pine
Pseudotsuga menziesii (P. taxifolia)	Douglas fir
Sequoia gigantea	Big tree
Taxodium distichum	Bald cypress
Taxus baccata	Common yew
Taxus cuspidata	Japanese yew
Thuja occidentalis	White cedar
Thuja orientalis	Chinese thuja
Thuja plicata	Western red cedar
Thuja standishii	Japanese thuja
Thujopsis dolobrata	Hiba
Tsuga canadensis	Eastern hemlock
Tsuga heterophylla	Western hemlock
Tsuga sieboldii	Japanese hemlock

8.4 Index to co-authors

Electronic version

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