(Austria) Special issue: "D. Grill"	Vol. 45	Fasc. 3	(355)-(362)	1.9.2005

Seedling Development of *Araucaria araucana* (Mol.) K.Koch

By

J. S. SIM & M. TESCHE[1)]

Key words: *Araucaria araucana*, seedlings, development, dry matter accumulation, photosynthesis.

Summary

SIM J.S. & TESCHE M. 2005. Seedling development of *Araucaria araucana* (Mol.) K.Koch. - Phyton (Horn, Austria) 45 (3): (355)-(362).

Seedlings were grown from seeds of the Chile Pine in defined conditions and some of their morphological and physiological development parameters have been examined. The seeds were harvested from a population of Chile Pines at the foot of the Llaima volcano in south Chile. Already during the stage of seedling development, the Chile Pine shows clear signs of its adaptation to the extreme site conditions. Among them are, for example, the big seeds that are rich in nutrients, the development of a far-reaching highly branched root system, the high light requirement and the temperature optimum for photosynthesis.

Introduction

The Chile Pine *(Araucaria araucana* (Mol.) K.Koch) is a bizarre peculiarity among the tree species that form forests in Chile and Argentine (Fig. 1).

In Chile, the tree is found in two distinctive areas:

I. the Andes Cordilleras between 37 and 40 ° s. latitude, up to heights of 1,800 m ASL

II. the Coastal Cordilleras between 37 and 38 ° s. latitude, up to heights of 1,000 m ASL.

The uniqueness of this species, its survival in extreme habitats, which are often covered with volcanic ashes, and its special phylogenetic features have been the reason for taxonomic, vegetational and silvicultural examinations for more than 200 years now.

[1)] Institut für Botanik, Technische Universität Dresden, Mommsenstraße 13, D-01062 Dresden, Germany.

At an early stage, researchers focused their attention on the seeds; for one reason to prepare the introduction of the Chile Pine to other countries and continents (BANKS 1795, quoted in BARNES 1871) and also to find explanations for the role the seeds play for the reproduction and the spreading of the tree species in the habitat (e.g. NEGER 1897 or FINCKH & PAULSCH 1995).

Only in 1971, DUHME & FUCHS gave a short description of the germination of the *Araucaria* seeds and their becoming seedlings. Both authors were interested in the cultivation of Chile Pines in nurseries.

It was our goal to discover new information about some physiological characteristics during the development of *Araucaria araucana* seedlings by comparing them with seedlings of other species and their development and to find out about possible peculiarities of the *Araucaria* seedling development which could explain their survival in extreme habitats.

With this study we intended to continue the examinations made by Franz NEGER[*]* 1897 and establish the basis for a joint research project between the newly found Institute of Botany at the Technische Universität Dresden and the Institute of Biology of the Univ. Talca de Chile. This project is supposed to focus on the influence of environmental factors (in particular volcanic action) on *Araucaria*.

As far as we know there are no detailed studies of the germination conditions and the development of *Araucaria araucana* seedlings. However, they are inevitable for the explanation of stress and adaptation mechanisms (TESCHE 1989) or for the comparison of the physiological performance of various species (TESCHE 1968, TESCHE & ZENTSCH 1980).

Therefore, we attempted to germinate seeds of *Araucaria araucana* of known origin in defined conditions and analyse the development of the seedlings.

Material and Methods

The tests were carried through with *Araucaria araucana* seeds from trees that grow in a habitat at the foot of the Llaima volcano.

Immediately after their harvest by the end of September, the seeds were carried by air to Dresden and stored at the Botanical Institute of the TU Dresden in airtight (Fig. 2) bottles in a refrigerator at 4-5°C.

The outer shell of the seeds was removed to accelerate germination. Subsequently, the seeds were sowed in Seramis substrate in plastic pots (Fig. 3) and put in a phytochamber (NB4019 m, manufactured by Nema, Netzschkau) for germination, in the conditions of Table 1.

The cultivation pots rested in water-filled saucers and were watered once every three days.

Measurements of the gas transfer and the influence of light and temperature on the photosynthesis were made using the portable mini cuvette system HCM-1000 manufactured by Walz (Effeltrich).

[*] NEGER worked as a teacher at the German school in Conception (Chile) between 1893 and 1897 and from 1921 to 1923 as head of the Botanical Institute at the TH Dresden. This Institute was closed in 1968 and reopened in 1993.

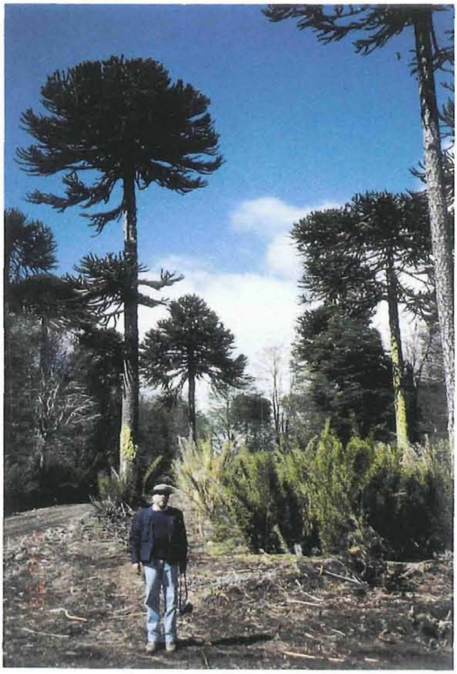

Fig. 1. Chile pines in NP Conguillio.

Fig. 2. *Araucaria araucana* seeds.

Fig. 3. *Araucaria araucana* seeds in plastic pots with SERAMIS substrate.

Table 1. Growth conditions during the development of the seedlings.

parameter	light phase	dark phase
temperature (° C)	25	20
rel. humidity (%)	60	60
lighting (PAR: μmol photons m^{-2} s^{-1})	100	-
duration (hrs.)	12	12

Results and Discussion

Development of *Araucaria araucana* seedlings

The germination rate of the seeds in the conditions described was approximately 40%. About two days after sowing, the *Araucaria araucana* seeds began to germinate and the stages of development given in Table 2 and Fig. 4 could be observed at the times indicated.

Table 2. Development stages of *Araucaria araucana* seedlings.

stages	radicula & primary root (mm)	side root 1st order (mm)	side root 2nd order (mm)	hypocotyl (mm)	sprout (mm)	duration (days)
1	visible	-		-	-	2
2	until 15	-		visible	-	5
3	„ 20	-		until 4	-	7
4	„ 40	-		„ 8	-	11
5	„ 60	-		„ 10	-	13
6	„ 80	visible		complete	visible	16
7	„ 90	until 5		-	until 4	19
8	„ 100	„ 10		-	„ 8	23
9	„ 120	„ 15		-	„ 10	27
10	„ 140	„ 30	visible	-	„ 15	31
11	„ 160	„ 45	until 5	-	„ 30	35
12	„ 180	„ 65	„ 10	-	„ 40	39

The seeds rapidly developed many roots. Already after 14 days at stage 6, side roots of the 1st order grew from the long primary roots that were up to 80 mm long. At stage 10, these side roots brought forth side roots of the second order. At stage 12, the seedlings finally showed shoots of 40 mm and a well-branched root system that reached 180 mm into the substrate.

However, the individual development varied from seedling to seedling so that they showed different development stages at a certain time after sowing. For the physiological tests, individuals of the same development stage have generally been chosen.

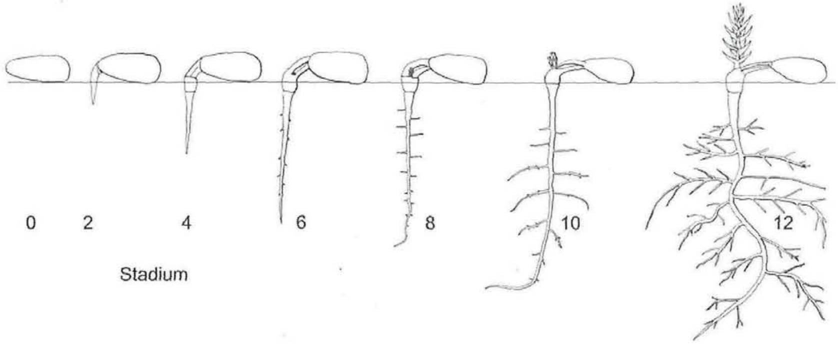

Fig. 4. Developmental stages of *Araucaria araucana* seedlings.

Dry matter accumulation by *Araucaria araucana* seedlings

The 1,000 seed weight of the seeds used in the testing was approximately 2,566 g. The outer shells of the seeds accounted for 744 g of the dry matter, 1,749 g were endosperm and the embryos had actually only 73 g of the dry weight. In other words, in a seed of 2,566 mg weight, the dry mass weight of the embryo is only 73 mg.

Until the seedlings are at the 12th stage, they consume approximately 1,396 mg of nutrients contained in the endosperm for their development. The 73 mg embryo becomes a 933 mg seedling (Table 3).

Table 3. Dry mass accumulation of seedlings of various tree species. [1] and [2] SIM & TESCHE 1998a,b.

	dry weight (mg)					
	endosperm			seedling (without endosperm)		
stage	*Araucaria araucana*	*Ginkgo*[2] *biloba*	*Pinus*[1] *koraiensis*	*Araucaria araucana*	*Ginkgo biloba*	*Pinus koraiensis*
0	1749	537	165	73	9	8
9	1103	399	16	128	81	109
12	353	235	0	933	206	195

Effects of light and temperature on the gas transfer of *Araucaria araucana* seedlings

The optimum photosynthesis conditions of *Araucaria araucana* seedlings with regard to temperature and light at stage 12 have been determined. The results are shown in Fig. 5 and Fig. 6.

The figures demonstrate that the temperature maximum of the photosynthesis is obtained at 28° C and the optimum temperature range is between 25 °C and 30 °C (Fig. 5).

The reaction of *Araucaria araucana* seedlings to a rising light intensity is a steep increase in photosynthesis which starts levelling out at approximately 300 µmol photons m^{-2} s^{-1} and obtains its light-dependent maximum, its light saturation at 800 µmol photons m^{-2} s^{-1} (Fig. 6).

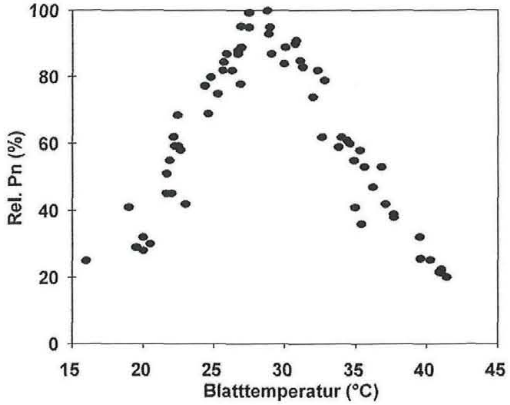

Fig. 5. Effect of temperature on the photosynthesis (Ph) of *Araucaria araucana* seedlings.

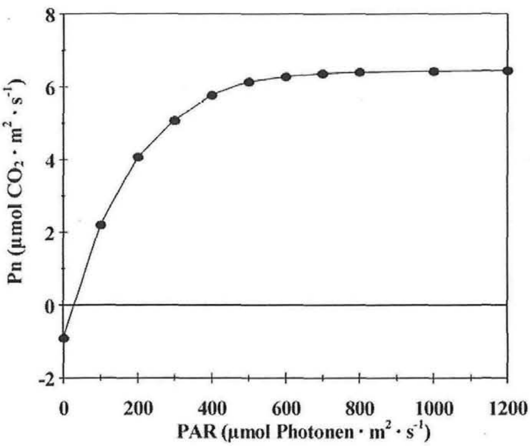

Fig. 6. Effect of light radiation on the photosynthesis (Pn) of *Araucaria araucana* seedlings.

Comparison of the physiological parameters of *Araucaria araucana* seedlings with those of other tree species

As we have shown it is possible to divide the development process of *Araucaria araucana* seedlings into 12 stages using visible morphological characteristics. As a result, the physiological and biochemical test results can be compared with the data obtained for other tree species independent of the cultivation conditions. For example, Table 4 shows the photosynthetic activities of the seedlings of *Fagus sylvatica* (KIRCHHOFF 1989), *Ginkgo biloba* (SIM & TESCHE 1998b) and *Pinus koraiensis* (SIM & TESCHE 1998a) at stage 12 in comparable measurement conditions and for a light intensity of 200 µmol photons m^{-2} s^{-1}. In the same conditions, the *Araucaria araucana* seedlings had the smallest CO_2 absorption rate in terms of dry matter and the highest CO_2 absorption rate as regards a seedling. These relations are maintained for light saturation as well.

Table 4. Photosynthetic performance of seedlings of various tree species (for 200 µmol photons $m^{-2} \cdot s^{-1}$). KL: seedling, TS: dry mass. [1] and [2] SIM & TESCHE 1998 a,b, [3] KIRCHHOFF 1989.

seedlings (stage 12)	seedlings (mg TS)	assimil. organs (mg TS)	CO_2 absorption (mg CO_2 gTS^{-1} h^{-1})	CO_2 absorption (mg CO_2 KL^{-1} h^{-1})
Araucaria araucana	933	870	4.4	3.83
Pinus koraiensis[1]	231	161	8.9	1.43
Ginkgo biloba[2]	190	126	18.5	2.31
Fagus sylvatica[3]	220	179	7.5	1.34

Both the heavy, rich seeds and the development of an extensive root system and a robust seedling from the nutrients of the seed ensure the good development of the seedlings and the stabilisation of the young plants of the species in the extreme conditions of the Andes. The comparatively high temperature optimum and the high light requirement of the *Araucaria* seedlings may serve as an explanation why the plant grows in rather open habitats and why rejuvenation of *Araucaria* failed beneath dense *Chusquea culeou* populations (FINCKH & PAULSCH 1995).

The data obtained in our testing of the seedling development of *Araucaria araucana* clearly shows that the morphological attributes and the physiological performance of the seedlings provide favourable growth conditions for the young tree and allow its stable development in an ecological environment.

Acknowledgements

We would like to thank Prof. Dr. rer. nat. San MARTIN of the Institute of Botany, Univ. of Talca (Chile) for providing us with the *Araucaria* seeds and Dipl. Forsting (FH) B. SCHULZ of the Institute of Botany, TU Dresden (Germany) for the drawing of Fig. 4.

References

BANKS J. 1795. - In: BARNES J. 1871. *Araucaria imbricata*. - The Gardener's Chronicle. 43: 1515-1516. London .

DUHME F. & FUCHS K. A. 1971. *Araucaria araucana* - ihre Anzucht. - Deutsche Baumschule 5: 156-157.

FINCKH M. & PAULSCH A. 1995. Die ökologische Strategie einer Reliktkonifere. - Flora. 190: 365-382.

KIRCHHOFF P. 1989. Die Keimlingsentwicklung von *Fagus sylvatica* L. - Diplomarbeit, Tharandt.

NEGER F.W. 1897. Die Araucarienwälder in Chile and Argentinien. - Forstliche Naturwissenschaftliche Zeitschrift 6: 416-426.

SIM J. S. & TESCHE M. 1998a. Keimungsversuche mit *Pinus koraiensis* - Samen. - AFZ. 21: 1300-1302.

— & — 1998b. *Ginkgo* - Keimlinge photosynthetisch höchst aktiv. - Deutsche Baumschule 2: 43-45.

TESCHE M. 1968. Zur Physiologie und Biochemie umfallkranker Keimlinge von *Pinus sylvestris* L. - Thesis Martin-Luther - Universität Halle/Saale.

— 1989. Umweltstress. - In: SCHMIDT &VOGT H. (Ed.), Die Fichte, Bd. II/2, pp. 346-384. - Verl. Paul Parey, Hamburg and Berlin.

— & ZENTSCH W. 1980. The development of seedlings of *Pinus sylvestris* L. Symposium Scots pine forestry of the future. - Polish Academy of Science, Inst. of Dendrology Kornik. Papers: 219-228.