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Revitalization experiments on an old oak

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Summary

A common oak (*Quercus robur L.*) named "Bear-Oak" in South Westphalia, aged about 650, taller than 30 m and with a diameter of over 1.6 m is under preservation order. This tree was seriously ill in summer 1990. Visible causes were a lightning strike and infection with fungal saprophytes. The most obvious symptom was that rotten strong branches broke off from the crown.

The original intention of the natural protection agency in charge was to exempt the tree from the preservation order and to let it "die honourably." However, revitalization measures such as revitalization of the crown, restoration of lightning wounds, mycorrhization, and fertilization of specific sites were performed in September 1993 on the suggestion of the Research Institute for Mushroom Cultivation of the Rhineland Chamber of Agriculture in Krefeld. The outcome of these measures was recorded and monitored in the following years by scheduled recording of vitality parameters (extent of mycorrhization, density of foliage, periodic volume increase) to find out whether the overall health of the oak had improved. Although the development of these parameters at the time of the report demonstrates variation in the productivity/vitality of the tree, it also shows that the functional capacity of the oak has recovered to a normal level.

The vitalization measures can be assessed as successful, and intermediate to long-term survival of the tree appears to be established.

Introduction

The tree

The old oak (*Quercus robur L.*) to be examined is called "Bäreneiche" by the locals (i.e. "Bear-Oak"; however, this is an individual name, and it should not be confused with the American / Canadian Oak (*Quercus ilicifolia Wangenh.*). It is sited in the district of Siegen-Wittgenstein close to the city of Freudenberg. It is located on a border between the villages Nieder- and Oberholzklau and grows 330 meters above sea level (Fig. 1).

As an overview of the basic data at the beginning of the monitoring, the results are listed as follows:

- height: 31.0 m
- stem height: 12.0 m
- circumference at breast height: 5.02 m
- diameter at breast height: 1.66 m
- timber volume: 22.6 m³ with 18.0 m³ of stem wood and 4.60 m³ of branches
- canopy projection screen: 240 m²

In the list of natural monuments published by the department of Siegen-Wittgenstein in 1988, the Bear-Oak ranks number15 of natural monuments and is therefore protected by law. The oak holds the place as one of the trees with the thickest diameter in this area.

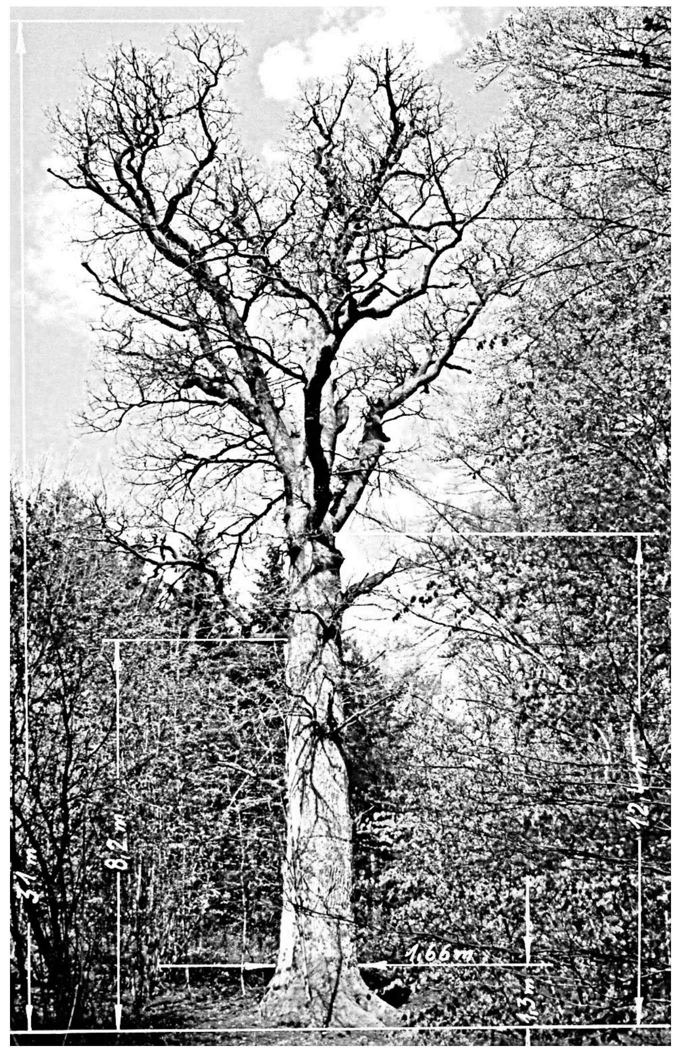

Fig. 1: The habit of the Bear-Oak in 2011

History of the tree

The exact age of the oak is not known. FRÖHLICH (1992) estimates that the tree was already mentioned around 1453. Therefore, we can assume that the tree already had a significant and noticeable size at this point of time.

The origin of this giant tree can be estimated to be around 1350. This assumption fits relatively well to the result of an extrapolation of the height-to-diameter development in the last 90 years. Assuming an age between 520 and 720 years, we can roughly calculate the age to be around 650 to 700 years.

The tree has reached such a high age for various reasons: firstly, it belonged to the "hohgewälde" of Keppel, i.e. an enfeoffment of the former monastery of Keppel that had tasks such as to provide the feudal lords, including the name-giving family Bähr (Behr) with enough building timber in the required dimensions (Hartnack, 1963). Secondly, the oak was already early an important boundary mark between the villages Nieder- and Oberholzklau (Bald, 1939) and between the territories or areas of influence, respectively, of the archdioceses Mainz and Cologne. Thirdly, being a boundary mark, the tree was specially protected according to the forest and wood regulations issued by the Count Johann of Nassau in 1562. Finally, compared to average forest locations in the Siegerland, the location of the oak is exceptionally well and deeply supplied with only moderately acidic soil water thanks to a hollow under a slope to the West (Becker et al., 2011).

The natural monument

For more than 100 years, the tree benefits from special awareness as an object of nature and natural monument protection. Schlieckmann (1904), Förster (1914), Jung (1932) as well as Hofmann (1940) and Fröhlich (1992) mention the "Bear-Oak" and describe it in detail as a tree worth seeing and deserving protection. The files of the lower landscape authority of the district of Siegen-Wittgenstein include a lively correspondence between this authority and the long-time commissioner for natural protection and landscape conservation of the district and town of Siegen, Hofmann, resulting in Hofmann's intensive and successful efforts to protect the oak.

First in 1937 and then again in 1938, the "Bear-Oak" was protected as a historic monument. The directive of the district law and order authorities of Arnsberg of 17 February 1988 refers to the tree as protected natural monument no. 15 in the district of Siegen-Wittgenstein. The "Bear-Oak" received its recent protection status as natural monument no. 4 by the entry into force of the landscape plan of Freudenberg on 18 December 2003.

Decay of the tree

During an assessment of the Bear-Oak in 1989, which was implemented by the forest department Siegen-North, the tree showed no signs of reduced vitality, yet. In summer 1990, the oak was struck by lightning, which caused a 20 meter long and 30-60 cm wide vertical fissure of the bark. The bark was blasted away between the medium crown and the trunk at the bottom. However, shortly after, the tree showed a sudden loss of vitality, expressed by the breakage of a strong crown branch. Furthermore, the appearance of the root rot fungus and other parasites indicating weakness were an obvious sign of physiological stress.

The lower landscape authority was notified about this by the Siegen-North forestry commission office. In 1991, the authority instructed a landscape architect to check state of health and stability of the oak. The consultant came to the result that the tree was seriously ill and recommended to let it die "honorably." Finally, i.e. in 1992, the lower landscape authority announced the release of the oak from the monument protection. It withdrew the decision in the same year.

Material and methods

In 1993, the idea emerged to recover the Bear-Oak by reconstruction treatments. The lower landscape authority agreed to the proposal of the Research Institute for Mushroom Cultivation of Krefeld and financially supported the required measures.

All investigations performed since 1993 aimed at the establishment and documentation of changes in the vitality of the Bear-Oak, including its mycorrhiza status.

The following vitality parameters were evaluated:

- mycorrhiza frequency of fine roots and their changes from year to year
- periodic volume increase (callus growth, circumference measurement)

The degree of foliage was documented and assessed from crown photos from the past years (Figs. 2 to 5).

Fig. 2: Foliation of the Bear-Oak in summer 1993

Fig. 3: Foliation of the Bear-Oak in summer 1996. The secondary crown is clearly visible at the lower part of the tree

Fig. 4: Foliation of the Bear-Oak in late summer 1997. The regeneration of the primary crown has begun

Fig. 5: Foliation of the Bear-Oak in early summer 2011

1. Remediation measures
Mycorrhization with depot plants
In 1993, the Bear-Oak was mycorrhized with depot plants. The following measures were performed:

- establishment of selected strongly mycorrhized young plants at the edge of the crown canopy area of the Bear-Oak
- stimulation of fine root formation by fertilization
- restoration of the tree top and the consequences of the lightning strike at the trunk

The measures taken to achieve mycorrhization of the fine roots of the Bear-Oak were based on earlier successful studies partially performed by the authors of the current paper (WÜSTENHÖFER, 1989; HILBER, 1991; HILBER and LELLEY, 1992; HILBER and WÜSTENHÖFER, 1992) and corresponding information provided by other workgroups (CASTELLANO, 1994). So-called mycorrhiza depot plants were used. In September 1993, we planted biannual seedlings strongly mycorrhized with *Paxillus involutus (Batsch.) Fr.*, strain W-50, in six groups into the root area of the Bear-Oak, at the edge of its crown canopy area (Fig. 6). Two groups consisted of four and the other four of three seedlings each, i.e. ten beech and nine oak seedlings and one birch seedling. The seedlings were surrounded by a fence as a protection against browsing.

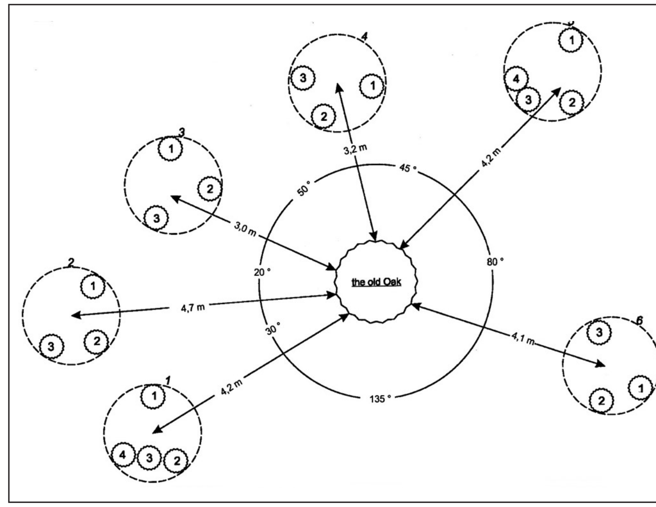

Fig. 6: Location of the depot plants

It was intended by this planting procedure to colonize new fine roots of the Bear-Oak with *Paxillus involutus (Batsch) Fr.* from the depot plants, because our earlier studies demonstrated intensive mycorrhization of oaks by this fungal species.

Based on the paper of WÜSTENHÖFER (1989), we performed the stimulation of fine root formation of the Bear-Oak by selective small-site fertilization using long-term fertilizer (Osmocota Plus, Sierra) acting for approximately 12-14 months; during this period, it successively releases a mixture of nitrogen, phosphate, potassium, and magnesium. 20 g of Osmocota were transferred into every planting hole of the depot plants.

We evaluated the results of the mycorrhization process first in 1995. Then the evaluation was repeated for five times. For this purpose we had defined six fine root sampling sites around the tree, all situated 80 to 120 cm away from the depot plants, to ensure that the fine roots detected in the soil samples were actually all of Bear-Oak and not of depot plant origin.

We met these requirements also in fine root sampling in later years. Root samples were taken with a short core sampler (25 x 6 cm). The samples containing fine roots were packed into plastic bags and kept cool (1-3 °C) until examination.

The fine roots in the soil samples were thoroughly cleaned under running water. Mycorhizza mostly remained undamaged. The cleaned root samples were kept in a water bath until evaluation.

Only fine roots with a maximum diameter of 2 mm were included in the investigations of the mycorrhiza frequency of the Bear-Oak. We performed one stereo-microscope analysis each for one meter of fine root system to establish absolute mycorrhiza frequency. In most cases, we also differentiated the detected mycorrhizas according to color and surface structure.

Restoration of the treetop
Restoration of the treetop, removal of dry branches, and the consequences of lightning strike, removal of dry bark between the intermediate treetop and the trunk base were performed by a member of the "Arbeitsgemeinschaft Neue Baumpflege." The measure was performed without lift platform to prevent compression of the soil around the Bear-Oak and injury to the tree (Fig. 7).

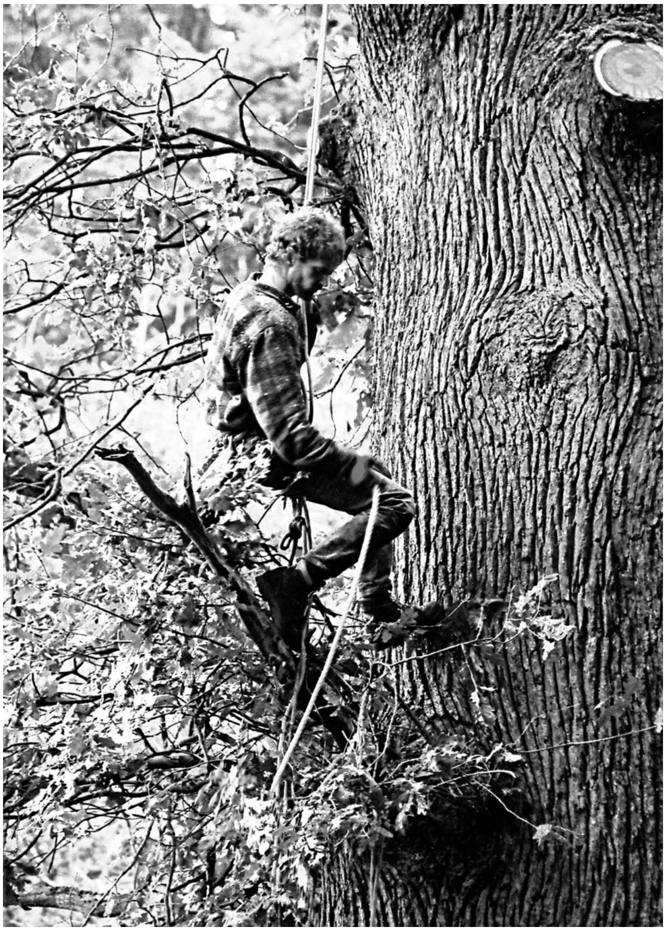

Fig. 7: Remediation of the crown of the Bear-Oak without use of machinery

Fig. 8: Wound of the Bear-Oak, caused by a stroke of lightning

2. Evaluation parameters

Circumference measurement

In 1995 and 1996, circumference measurement was performed with a measuring tape. It was laid around the trunk of the Bear at "breast height," i.e. 1.3 m above soil.

Callus growth

It was intended to document the growth potential of the Bear-Oak not only by circumference measurement but also by measurement of periodic callus growth at the edges of the lightning strike traces (Fig. 8).

Already in 1993, a significant growth of scar wall tissue started. The growth of these scar bulges is considered a special case of circumference growth also based on the division of meristem cells induced by wall stimuli. However, due to its orientation (Fig. 9), growth takes place in radial rather than tangential direction. Measurement was performed every 14 days at 5 measurement sites, one above the other, by determination of the distance of the two bulge edges (Fig. 10) with an exactly measuring and specifically horizontally adjusted caliper square (Fig. 11).

Annual increase is very variable. In the first years, an increment could be observed suggesting increasing vitality of the Bear-Oak; however, it was clearly reduced since 1998. The reason was that callus growth deviated from its earlier preference, i.e. the tangential direction. The callus bulges increasingly penetrated the slowly rotting superficial sapwood, making it increasingly more difficult and inaccurate to record callus growth, so that the actual increase was only partially identified.

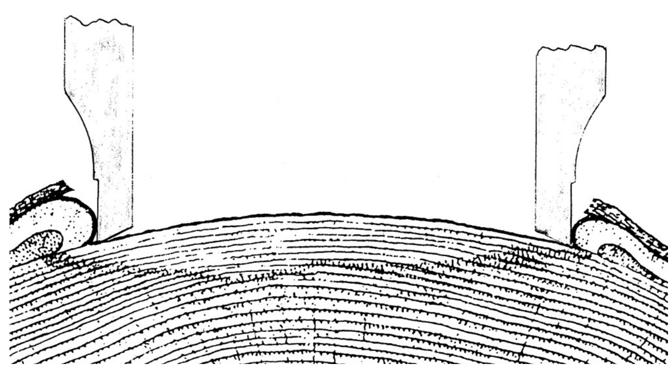

Fig. 9: Schematic figure of the location of the bulges on both sides of the wound caused by the stroke of lightning (according to Butin, 1989)

To stop this tendency, two stainless steel sheets, each 80 mm wide, were mounted in spring 2001 to the left and right edges of the lightning wound and fixed below the callus bulges suggesting a function as "guardrails" to redirect callus growth into tangential direction (Fig. 12).

However, it already became obvious in 2003 that callus growth demonstrated a type of incompatibility reaction and was more or less guided into radial direction, but this time to the outside. Due to this

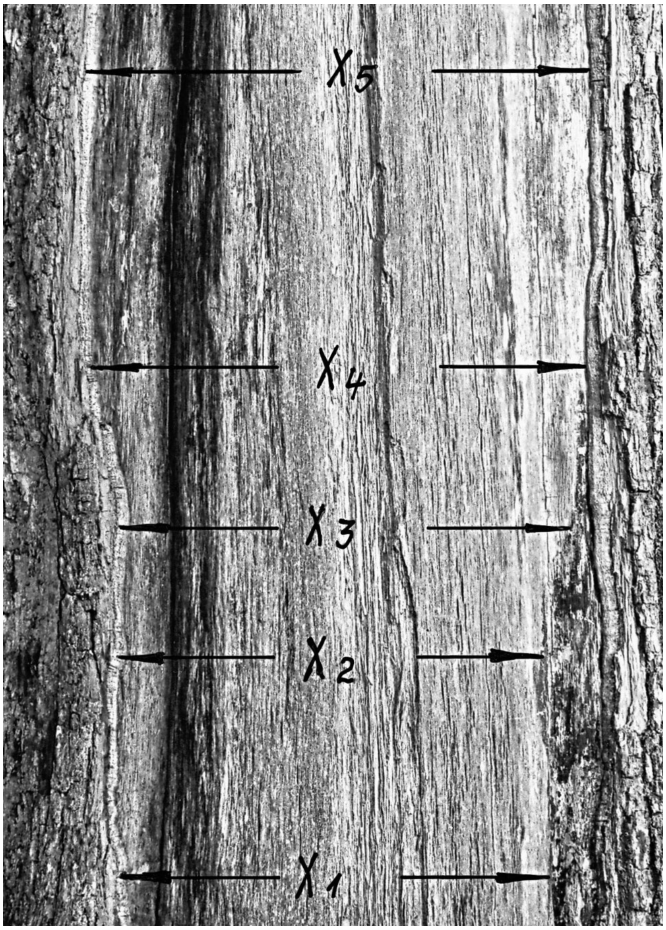

Fig. 10: Location of the measuring points to measure the distance between the edges of both bulges

Fig. 11: Horizontally adjusted calipers for measuring the distance between both bulges

phenomenon, callus growth was included into the vitality assessment of the Bear-Oak only until 1999. Then measurements along the guardrails were only performed occasionally.

Diameter measurement by a permanent measuring tape

On 24 April 2001, a permanent measuring tape according to WEIHE (MAESSEN and WEIHE, 1973; SPELSBERG, 1992) was laid around the trunk of the Bear-Oak in a height of approximately 3 m (Fig. 13).

Fig. 12: Stainless steel crash barriers for steering the callus growth tangentially

Fig. 13: Permanent measuring tape to record the change in the diameter of the Bear-Oak

The tape was tightened with a spring; its scale allows direct reading of the diameter or its changes, respectively. In the first years, the measuring tape was read two times a year, i.e. before start of the vegetation period (April) and at its end (October). However, it soon appeared that only the autumn readings gave correct results, because swelling of the wood body in winter interferes with correct spring readings. Unfortunately, the permanent tape was destroyed for unknown reasons in February 2007. Due to the damaging of the tape, the year 2007 is an outlier anyway.

Clearing of environment

On 13 March 1989, the lower landscape authority of the district of Siegen-Wittgenstein asked the wood cooperative of Oberholzklau in its role as the proprietor of the Bear-Oak and neighbored spruces, if they would consider a change in cultivation near the Bear-Oak for its protection. The forestry office of Siegen-Nord has been notified of this inquiry. It stated at that time that the oak would not be acutely threatened by the spruces; at most competition would exist between the oak and the neighbored spruces. As a matter of prevention and to avoid the risk of a later revision of the spruce edge, it was proposed to keep a circle with a radius of 20 m around the oak free form spruces. Finally, in the end of November 1994, a rectangular angled strip of spruces with a width of 4 to 10 m (approx. 400 m²) was cleared (Fig. 14), resulting in the cutting of about 200 spruces. Consequently, the distance between the remaining spruces and the crown canopy area of the oak was 6 to 12 m. The cleared strip was left to natural succession.

Fig. 14: Clear cutting around the Bear-Oak in autumn 1994

Results

Mycorrhization with depot plants

The changes in mycorrhiza frequency in the fine root system of the Bear-Oak are shown in Tab. 1. Note the large differences in mycorrhiza frequency at the individual sampling sites throughout all samplings. However, it is clear that mycorrhiza frequency tremendously increases at five of six sampling sites after 1995. At sampling site III, we first detected a strong reduction in mycorrhiza frequency in 1996. However, later samples demonstrated a satisfying result also at this site.

The mean mycorrhiza frequency of all sampling sites over the complete monitoring period demonstrates a tremendous increase after 1995. With one exception, it was clearly higher than 50%. In 2004, mean mycorrhiza frequency was only somewhat higher than 50%. However, four years later it increased to more than 56%.

The 1995 evaluation detected mostly dark-brown mycorrhiza structures with a smooth surface; the dominance of these structure even increased in the 1996 evaluation, allowing the conclusion that *Paxillus involutus (Batsch) Fr.* has established itself on the root rips of the Bear-Oak. The investigation of mycorrhiza color and surface structure in 1997 demonstrated that the dominance of mycorrhiza with a dark-brown, smooth surface had consolidated; however, also a clear increase in other mycorrhiza types could be observed (black, with radiating hyphens, beige, clubby swellings, and smooth). Six years after mycorrhization of the Bear-Oak, the authors detected only black and light and dark brown mycorrhiza on its fine roots. Only the last evaluation in 2008 demonstrated in addition to the still existing black and dark brown mycorrhiza types individual occurrences of white mycorrhiza on the fine roots of the Bear-Oak. However, a succession of mycorrhiza fungi over a period of 15 years is a natural event; it has been reported by authors such as Ricek (1980), who repeatedly investigated the mycorrhiza population of a spruce area over 24 years.

Circumference measurement

The results of initial circumference measurements are summarized in Tab. 2. The increase in diameter of 2.6 established in the 1996 vegetation period appeared comparably plausible; however, the apparent increase in diameter of 0.3 mm in the winter months of 1995/1996 revealed the unreliability of the measuring method, when the measuring tape was re-applied for every individual measurement. The assumed source of error was the exceptionally rough trunk surface resulting in significant impact of the actual tape position on the measured result. Therefore, this investigation was discontinued.

Tab. 2: Measurement of the circumference of the Bear-Oak in 1995 and 1996

Date of measurement	circumference (mm)	diameter (mm)
8.10.1995	4895	1558,1
24.3.1996	4896	1558,4
6.10.1996	4904	1561,0

Callus growth

Tab. 3 shows the established annual increase in wound callus from 1994 to 1999 at the 5 measured sites and its mean. Fig. 15 illustrates the variation in callus increase in the individual years of monitoring. Fig. 16 shows the annual callus increase through the same period.

The annual development of callus growth corresponds to the general ideas on the diameter growth of woods in the vegetation period (Kramer, 1988) and indicates a normal aspect of the Bear-Oak.

Tab. 1: Changes on mycorrhiza frequency on the fine root system of the Bear-Oak between 1995 and 2008

Year	site of root samples No. I			site of root samples No. II			site of root samples No. III			site of root samples No. IV			site of root samples No. V			site of root samples No. VI			average in %
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	
1995	536	195	**36,4**	609	170	**27,9**	625	280	**44,8**	550	213	**38,7**	640	315	**49,2**	693	253	**36,5**	**38,9**
1996	1021	493	**48,3**	962	592	**61,5**	710	173	**24,4**	382	224	**58,6**	879	630	**71,7**	1025	621	**60,6**	**54,2**
1997	1530	834	**54,5**	2381	1687	**71,0**	887	369	**41,6**	2141	1060	**49,5**	2220	1759	**79,2**	2490	1873	**65,5**	**60,2**
1999	882	538	**60,9**	760	349	**45,9**	823	444	**53,9**	860	610	**70,9**	1027	668	**65,0**	917	477	**52,0**	**58,1**
2004	593	290	**48,9**	978	484	**49,5**	700	326	**46,6**	558	286	**51,2**	769	488	**63,5**	519	219	**42,2**	**50,4**
2008	292	144	**49,3**	226	102	**45,1**	448	264	**58,9**	244	172	**70,5**	291	150	**51,5**	325	212	**65,2**	**56,7**

Legend: 1 = total number of root tips
2 = number of root tips with mycorrhiza
3 = mycorrhiza frequency in %

Tab. 3: Callus-growth on the Bear-Oak at 5 measured sites (X1-X5) between 1994 and 1999

Year	X1 (mm)	X2 (mm)	X3 (mm)	X4 (mm)	X5 (mm)	average (mm)
1994	3,2	3,5	3,8	3,2	3,7	3,5
1995	3,6	3,7	3,7	2,5	2,4	3,18
1996	5,9	6,8	6,1	5	4,7	5,7
1997	3,6	6,6	5,6	5,6	6	5,48
1998	2,2	6	4,3	4,3	3,9	4,14
1999	1,8	3	2,4	2,4	3	2,52

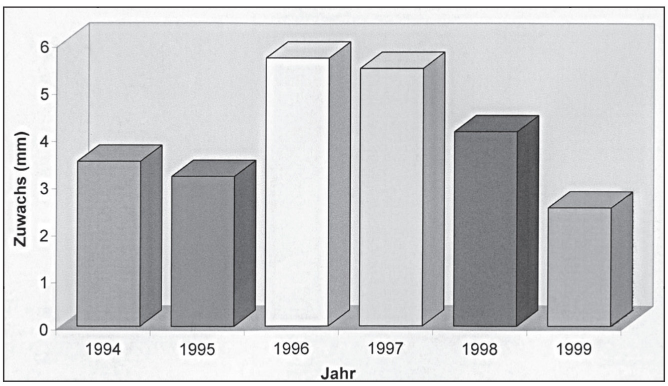

Fig. 15: Fluctuation in the averages of the callus-growth between 1994 and 1999

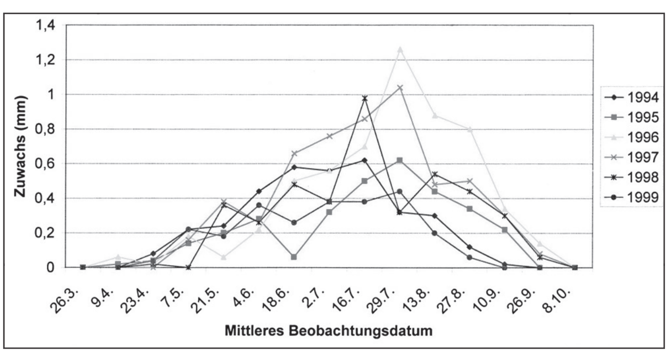

Fig. 16: Detailed annual results of the callus-growth between 1994 and 1999

As already discussed in the chapter "materials and methods", the systematic measurement of callus growth was discontinued in 1999.

Diameter measurement by a permanent measuring tape

The results are summarized in Tab. 4. Increase considerably varied in individual years. The largest increase in diameter, i.e. 3.8 mm, was established in 2009; the smallest increase so far was 1.0 mm in 2010. Accordingly, width of annual growth rings ranged from 1.9 to 0.5 mm. The mean increase over nine years was 1.33 mm.

Clearing of environment

The proximity to the spruces before and after 1994 did not interfere with the Bear-Oak. The clearing of environment did not improve the situation. It should be noted that the clearing of spruces in 1994 was not the only measure that has been performed in the more recent history of Bear-Oak. In 1976, a spruce area reinforced at that time has been exploited completely. However, it is unknown, whether this happened to the favor of the Bear-Oak or for specific reasons of the wood cooperative.

Tab. 4: Results of the diameter measurement on the Bear-Oak between 2001 and 2011 using a permanent measuring tape

Date of measurement	result (mm)	previous year's result (mm)	Year of growth	Increase in diameter (mm)	Width of annual ring (mm)
24.04.2001	35,0	-	-	-	-
18.10.2001	37,2	35,0	2001	2,2	1,1
15.10.2002	40,7	37,2	2002	3,5	1,75
16.10.2003	42,3	40,7	2003	1,6	0,8
12.10.2004	44,7	42,3	2004	2,4	1,2
13.10.2005	45,9	44,7	2005	1,2	0,6
02.10.2006	49,0	45,9	2006	3,1	1,55
05.10.2007	76,7	77,5	2007	-0,8 *)	-0,4 *)
14.10.2008	78,2	76,6	2008	1,6	0,8
30.10.2009	82,0	78,2	2009	3,8	1,9
05.10.2010	83,0	82,0	2010	1,0	0,5

*) Measurement error due to demolition and replacement of the measuring tape

Discussion

Mycorrhization with depot plants

Mycorrhiza rather than roots represents the major food ingestion organs of most plants. It is generally accepted today that even the expansion of plants on land millions of years ago was only possible by the establishment of symbiosis with fungi, i.e. mycorrhiza (SMITH and READ, 2008). It has been known for half a century that mycorrhiza has a positive effect on nutrition and water supply of the partner plants, that plants exploit a larger soil volume than without mycorrhized fine roots, and the mycelium mantle around the fine root tips of the partner plants also can protect against soil-borne infections. Mycorrhiza also helps plants to survive (climate- or soil-related) stress better (MOSER, 1963; MARX, 1972; MARKS and KOZLOWSKI, 1973; MARONEK et al., 1981; BERRY, 1982).

Already TRAPPE (1964) concluded from the shift in species composition of mycorrhiza fungi as a consequence of immission impact that a number of fungal species are better adapted to extremely dry soil and climate conditions. The supporting effect of a healthy, luxuriant mycorrhiza on the tree partner has prompted MOSER (1958a, 1958b) to use specifically mycorrhized seedlings in the reforestation of subalpine areas with Swiss stone pine *(Pinus cembra L.)*. For the same reason, MEYER (1968) recommended the specific use of mycorrhized seedlings or cuttings for the recultivation of waste pile and steppe areas.

MARX (1975, 1976) performed pioneering work with specifically mycorrhized seedlings of the loblolly pine *(Pinus taeda L.)* in the recultivation of hard coal strip mining areas. MARX also used mycorrhiza in other tree species, i.e. hickory tree *(Carya illinoensis Wangenh. K. Koch)*, American white oak *(Quercus alba L.)*, and American red oak *(Quercus rubra L.)*. It was essential in all these cases to use efficient fungal strains with a broad spectrum of host plants.

MOHR (1986) accurately said that a "harmonically appearing symbiotic balance between fungi and trees can be easily destroyed by environmental interference." The consequence is reduced mycorrhiza. The reduction in mycorrhiza then leads to suboptimum supply of the tree partner with nutrients and water, while the partner reduces the supply of the fungal partner. This process leads to fine root degeneration (BLASCHKE, 1985) and eventually to vitality loss of the tree. It is possible to stop and turn this process, provided that accordingly selected high-performance mycorrhiza fungal strains with a broad spectrum of efficacy are used (WILLENBORG, 1987; SCHMITZ, 1987; WÜSTENHÖFER, 1989; WILLENBORG et al., 1991).

The vitality loss of the Bear-Oak may have a number of causes. The lightning strike in summer 1990 may already have caused a secondary damage, because lightning strike occurs accumulated, when strong crown branches have become dry. Also fungal contamination in the area of the trunk base can be interpreted as the cause, but vice versa also as a consequence of vitality loss. Anyhow, the large number of dry branches that were removed during the revitalization of the crown suggests the strong decrease in life energy of the Bear-Oak.

The establishment of the mycorrhiza depot plants together with the long-term fertilizer obviously has stopped the decay process and initiated an increase in vitality of the Bear-Oak. This view is clearly supported by the results of absolute mycorrhiza frequency determination per running meter of fine roots. Three years after the revitalization measure, the mean of six samples was higher than 50% and – with one exception – even considerably higher. The use of depot plants for mycorrhization together with the stimulation of fine root growth around the Osmocota inoculation area proved to be a good measure. It also confirmed WÜSTENHÖFER'S (1989) results. By the establishment of depot plants together with lime treatment and fertilization in a damaged spruce growth area, WÜSTENHÖFER achieved a significant increase in the absolute mycorrhiza frequency of the sick spruces.

It has been a proven approach for this measure to use the resistant culture strain W-50 of *Paxillus involutus (Batsch) Fr.*, selected by WILLENBORG (1987). This fungal strain provided the best results under stress with a number of biotic and abiotic stress factors in *in-vitro* and *in-vivo* studies (WILLENBORG et al., 1990).

The reversal of the decay process of the Bear-Oak is not only demonstrated by the constantly good mycorrhization level of the fine roots, but also by all other measures success control.

Callus growth

It was obvious that the actual growth development would be always superimposed by swelling and shrinking processes at the open exposed sapwood. However, winter swelling is always compensated by sapwood shrinking in summer; the authors therefore assume that the actual growth development was recorded in the growth periods between 1994 and 1999.

Callus growth was demonstrated to take place on a sustainably high level. This finding indicates a remarkable vitality of the Bear-Oak.

Diameter measurement by a permanent measuring tape

The cause of the variation in diameter increase is unclear. Environmental conditions and/or pest in the year of evaluation or the year before may have played a decisive role.

The apparently small increase in 2005 may result from intensive acorn mast in 2004. At that time, more than 4 kg of acorn was collected below the Bear-Oak. Periodic mildew growth in the crown could be another cause of the variation in diameter increase. At least ZIEGLER (2010) reported dramatic impairment of the assimilation efficiency by mildew (*Microsphaera alphitoides Griff & Maubl.*) growth, mostly after leaf damage (Fig. 17).

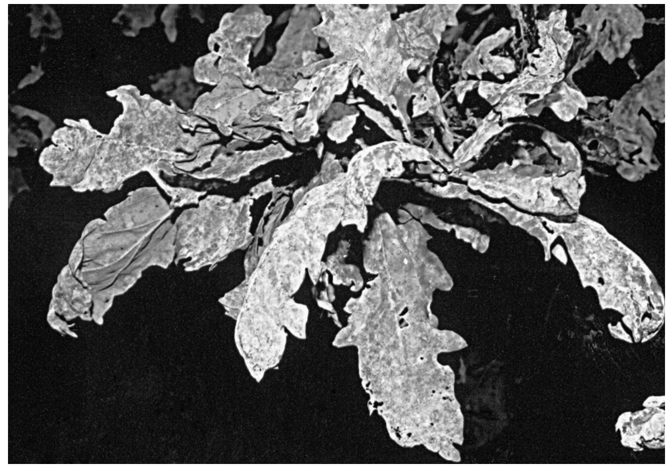

Fig. 17: Strong mildew (*Microsphaera alphitoides Griffon & Maubl*) infection of the Bear-Oak

However, overall increase in diameter of the Bear-Oak was in an order of magnitude comparable with comparably sized healthy oaks. E.g. SPELSBERG (2004) reported annual ring widths from 0.6 to 2.7 mm with a (weighted) mean of 1.86 mm in an analysis of data of the Federal forest inventory (BWI, 2002) involving 1452 oaks with diameters from 10 cm to more than 90 cm. Probably the mean annual ring width would have been even significantly smaller, if the sample portion of very thick oaks would have been larger in this study.

A comparison of these values with the results obtained for the Bear-Oak in 9 years allows the conclusion that the functional capacity of the oak is quite normal; thus it is "healthy" for its age and there is no need to classify it "sick."

Clearing of environment

In the West and the North of the Bear-Oak, an area of young spruces adjoins its site. In 1994, the spruces were 25 to 30 years old. At that time, they were 11 to 15.5 m high, while the adjoining Bear-Oak had a height of 31,0 m. Only at one site north of the Bear-Oak, spruces were high enough to grow up to approximately 1.5 m away from the crown of the oak. In all other directions, spruce tree were 4 m or farther away from the crown projection area. At no time, light competition existed between spruces and the oak due to the large difference in height of 15,5 to 20 m. Competition with respect to water or nutrients would only be expected, if the spruce area would have intruded into the crown canopy area of the oak over the complete width, thus exceeding the limit of the crown projection with the highest density of the fine roots of the oak. But even then, water competition probably would have been irrelevant due to the good site-related supply and the very different root systems of spruces and oak. The same applies to supply with nutrients. Therefore, it is considered improbable that spruces interfered with the growth of the Bear-Oak.

All results indicate that the Bear-Oak recovered 20 years after it had been officially given up to "let it die in honor" and 18 years after the revitalization measures discussed here. Its physiological performance characteristics and its appearance allow the prediction that it will survive the generation of its "service personnel" and perhaps even will live longer.

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