

LIVING STUMPS IN THE SIERRA NEVADA

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INTRODUCTION

In a dense forest that has been thinned recently there are often some tree stumps that are still alive and growing despite the loss of their green tops. Such stumps have been noted for many years and are known to be products of root-grafting between trees (Bormann and Graham 1957).

If light cutting or windfall occurs in a dense stand where root-grafting is common, food materials in the standing members of a grafted clump will move through root-grafts into the fresh stumps. Thus the cambium of a stump can continue to add increments of wood and bark.

This paper reports on studies of the properties of living stumps, their longevity, and their growth. Data are based on above-ground examinations of 25 living stumps of 6 species of Sierra Nevada conifers, and cursory observations of several dozen others. The stumps are on the La Porte Ranger District of the Plumas National Forest in California. Several are within the Challenge Experimental Forest which is operated by the Pacific Southwest Forest and Range Experiment Station.

GENERAL CHARACTERISTICS OF LIVING STUMPS

As a stump grows, a ring of callus tissue usually forms around its top. This callus sometimes grows across the entire cut surface, thus sealing and protecting it. Such

capped stumps become impervious to fungus and termite attack and may exhibit remarkable longevity (Fig. 1). Sugar pine stump No. 1 and red fir No. 9 (Table I) were completely capped.



FIG. 1. Douglas-fir living stump almost completely callused over. The tree was felled 17 years ago. Host tree is in left background.

TABLE I. Detailed measurements of living stumps

Species	STUMP			Tree age	Stump age	Tree rings per inch	Stump rings per inch	Width of new growth	Host distance	Probable crown class
	No.	Height	Dia.							
Sugar pine (<i>Pinus lambertiana</i> Dougl.)	1	<i>Ft.</i> 2.5	<i>In.</i> 28	<i>Yrs.</i> 75	<i>Yrs.</i> 17	<i>No.</i> 7	<i>No.</i> 19	<i>In.</i> 0.89	<i>Ft.</i> 3	Int.
	26	0.5	10	65	18	22	45	0.40	6	Sup.
Ponderosa pine (<i>Pinus ponderosa</i> Laws.)	2	2.0	28	50	23	4	64	0.36	3	Dom.
	3	3.0	21	75	17	4	113	0.15	4	Int.
	20	3.5	16	55	30	9	50	0.60	4	Sup.
	21	3.5	20	70	12	14	171	0.07	7	Int.
	22	3.0	20	70	15	7	100	0.15	6	Int.
California red fir (<i>Abies magnifica</i> A. Murr.)	5	1.5	13	70	20	14	34	0.59	2	Sup.
	6	1.0	8	70	22	25	28	0.78	3	Sup.
	7	2.5	15	60	22	12	51	0.43	1	Sup.
	8	4.5	16	70	10	11	50	0.20	3	Int.
	9	2.5	21	40	61	5	36	1.70	5	Int.
White fir (<i>Abies concolor</i> (Gord. & Glend.) Lindl.)	19	2.0	13	35	45	16	64	0.70	1	Sup.
	25	3.5	20	200	13	44	17	0.75	4	Sup.
Douglas-fir (<i>Pseudotsuga menziesii</i> (Mirb.) Franco)	10	9.0	36	70	22	—	33	0.66	1	Dom.
	16	3.5	26	—	53	—	28	1.90	4	Codom.
	17	2.5	18	60	17	13	24	0.70	3	Int.
	18	3.0	33	120	87	—	38	2.30	1	—
	23	7.0	34	60	30	10	30	1.00	2	Codom.
	24	3.0	19	50	15	10	23	0.65	23	Dom.
Incense-cedar (<i>Libocedrus decurrens</i> Torr.)	11	2.5	19	50	20	7	24	0.85	11	Int.
	12	1.5	20	50	21	7	24	0.88	7	Int.
	13	1.5	20	50	22	13	18	1.20	6	Int.
	14	0.5	10	45	27	19	59	0.46	7	Sup.
	15	3.0	18	50	22	22	22	1.00	12	Dom.

On some stumps only one major root is translocating food from one or more host trees. In this case only that sector of the stump directly above the root remains alive (Fig. 2).



Fig. 2. Douglas-fir living stump grafted on only one side. The host tree shown in background is 10 ft distant.

The bark of a living stump is distinctive for its "normal" or "live" appearance which contrasts strongly with the lackluster look of typical dead bark. Occasionally a heavy flow of pitch may issue from cracks in the bark or callus.

Because it is encased in new wood and bark, the old wood in living stumps is often well preserved (Fig. 3). The cutting that produced the stumps shown in Figures 1-3 also left many "dead" stumps. After 17 years the standing dead ones could be torn apart easily while the living ones would still resist axe blows on the old exposed surfaces.

The wood of the living shell gradually differentiates into heartwood and sapwood. Thus a radial section from the pith outward discloses original heartwood, original sapwood, new heartwood, and new sapwood. This pattern is especially marked in Douglas-fir (*Pseudotsuga menziesii*) and the true firs (*Abies* sp.).

DETAILED STUMP MEASUREMENTS

In assembling the data presented in Table I measurements and estimates were made according to the following criteria:

Height—From highest point of living tissue to the ground, to nearest $\frac{1}{2}$ ft.

Diameter—Taken below undercut on cut stumps, at

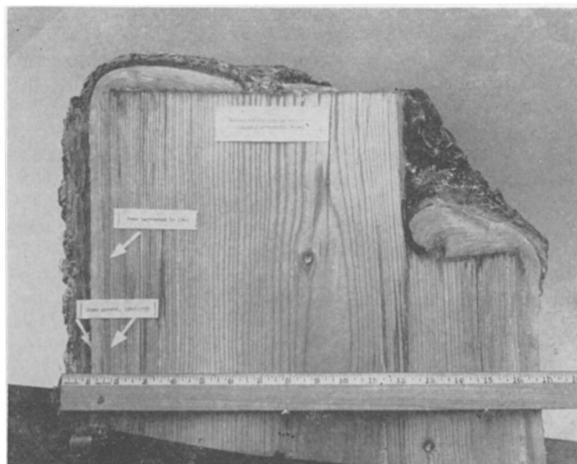


FIG. 3. Radial section through Douglas-fir living stump showing condition of wood and change in growth rate since tree was felled. Note differentiation of new wood into heartwood and sapwood. This is stump No. 17 in Table I.

breast height on taller natural stumps. Given to nearest inch.

Tree age—Estimated age of tree at time of felling, from ring counts.

Stump age—Number of annual rings counted in living shell.

Tree rings per inch—Number of rings in last radial inch of tree prior to felling.

Stump rings per inch—Average number of rings per inch of new growth.

Width of new growth—Thickness of new growth (new xylem), to nearest 0.01 inch.

Host distance—Distance to nearest tree of same species, exclusive of seedlings and saplings, to nearest foot.

Probable crown class—An estimate of former crown position made by observing stump size and original growth rate compared to those of likely hosts, and observations of the crowns of neighboring trees still standing.

DISCUSSION AND CONCLUSIONS

The data in Table I indicate that even within a species, living stumps are highly variable. They can be initiated in trees as young as 35 years (white fir No. 19) or as old as 200 (white fir No. 25). One stump has persisted for almost a century (Douglas-fir No. 18), and a record exists of a Douglas-fir living stump persisting more than 200 years (Newins 1916).

Although living stumps have no green tops, water and food materials can be transported to heights of at least 9 ft (Douglas-fir No. 10).

Growth in the new tissue is usually, but not always, slower than in the tree before felling. In incense-cedar No. 15 the growth rate stayed about the same; in white fir No. 25 it almost tripled. Incense-cedar and Douglas-fir show the least change in growth rate, and ponderosa pine the greatest. The growth rate may be influenced by the size and number of sustaining root-grafts, or the number and vigor of the host trees. Former crown class may also be involved though these data are inconclusive.

The age of new growth may be determined by examining an increment core under low magnification. Ring spacing normally shows an abrupt change, marking the time of felling, and the old wood is either rotten, or in the pines, blue-stained or impregnated with pitch. How-

ever, even under magnification the age of some cores is difficult to establish because of the lack of contrast between springwood and summerwood. This is especially true in incense-cedar.

Most of the living stumps examined were within 6 ft of the nearest likely host, but two were more than 10 ft distant and one was 23 ft away. These are minimal distances; the stumps may have been root-grafted to trees further away than those judged the likely hosts. Indeed, there is a Douglas-fir living stump shown by root excavation to be grafted to a tree 50 ft away (Pemberton 1920). All 6 species mentioned in this report are probably capable of forming root fusions at the spacings commonly used in plantations.

Crown position is apparently not a factor in determining whether a cut tree can give rise to a living stump. This suggests it is not necessarily true that within a grafted cluster dominant trees pass on materials to suppressed trees, or vice versa, as has been suggested (Bormann and Graham 1959 Kuntz and Riker 1956). A considerable proportion of the stumps were from trees that were codominant or dominant before they were felled. Several of the stumps listed in Table I were created by a pole and piling harvest which tends to select smaller trees with little taper (inferior crown classes). Hence the trees in Table I may not be representative of all crown classes, yet despite this, dominants and codominants are well represented too.

Felling method is not a factor in the possibility of a living stump being produced. A saw-cut is probably most likely to heal over because it seldom disturbs the

cambium below the cut surface, but even ragged axe-cut stumps can stay alive (stumps Nos. 25 and 26). The splintered stubs of wind-felled trees are least likely to live but even they are represented by stumps Nos. 10 and 24 (Fig. 4).

To cover a stump the callus tissue must grow along a solid surface that can support it. If the center of the stump rots out before the callus reaches that area, horizontal growth is then replaced by growth downward into the hollow. In extreme cases where rot outpaces new growth considerably, the callus may grow down into the hollow along the inner wall of the living shell. In Douglas-fir No. 16 this occurred, and the stump is a hollow shell, lined with bark inside and out. Stumps like this frequently accumulate litter in their hollow centers, and so provide a seedbed for tree or shrub seedlings.

A root-grafted tree, when cut, does not always give rise to a living stump. During logging operations many stumps are stripped of their bark or splintered and mashed by moving logs and equipment. Their cambium is exposed to the air, and the cambial cells dehydrate. In the Sierra Nevada, fresh pine stumps are commonly attacked by the red turpentine beetle (*Dendroctonus valens* Lec.), whose larvae kill the cambium by girdling. This may be the cause of wholly dead trees and stumps whose grafted roots still live, a phenomenon reported by Bormann and Graham (1959).

In an old stand if the last surviving member of a root-grafted cluster is cut, its stump cannot continue to live though in the past it may have been joined to several other trees. Nor can any stand produce living stumps if it is cut too heavily. For these reasons the frequency of living stumps can be used as an index to the frequency of root-grafting only in lightly cut stands. There will always be more root-grafting in a stand than the numbers of living stumps indicate.

One interesting problem concerning living stumps is the means by which solutes are available to them. Because there is no green top, all manufactured foods must come through root-grafts from hosts. The lack of a top also excludes the possibility that solute movement is effected by transpiration pull or sap cohesion. The manner by which solutes move in trees is controversial. Living stumps may be valuable aids in the study of various theories which have been suggested for this phenomenon.

When a thinning is made, it is possible that the residual stand benefits from the formation of living stumps. To the forester concerned with timber culture, two possible effects seem preeminent and need further study: the effect on the host tree's growth rate, and the role of living stumps in restraining rot.

Because the living stump is maintained by nearby standing trees, it would be expected to exert a measurable influence on the growth of those trees. Terming these trees "hosts" does not infer that the living stump is a parasite on its neighbors, draining them of some of their vigor. There is no evidence that such a simple relationship exists; in fact, exactly the opposite may be true. For example, the root system of the living stump may contribute greatly to the absorptive capacity of the hosts. This may outweigh the parasitic effect, which is normally adequate for only token growth (Table I).

The implications of this possibility enter any situation where there is root-grafting. The use by a standing tree of the root system of a cut tree could help to explain why "thinning from below" (e.g. removal of trees of inferior crown classes) sometimes results in increased growth of the residuals. It may also explain the remarkable growth, after removal of dominants, in trees known to have been suppressed for many years.



FIG. 4. Naturally formed living stump of Douglas-fir. The tree was felled by wind. This is tree No. 10 described in Table I.

The role of living stumps in restraining the spread of rots is speculative. However, the "pipeline" function of root-grafts in spreading diseases from one tree to another has been reported in oak wilt where the movement of spores takes place through grafts (Kuntz and Riker 1956); and even fungal hyphae can spread through grafts by breaking down the cell walls of uninfected joined trees (Hafiz Khan 1910). Also living stumps are usually more resistant to rots than their dead contemporaries. Some are probably completely impermeable by virtue of a perfect callus cover. If such stumps had not lived, would the rot in their progressively deteriorating roots have spread to those of the host? Can the incidence of root rots in grafted stands be retarded by encouraging the formation of living stumps after thinning?

These questions can be answered only by further investigation.

SUMMARY

1. Twenty-five living stumps of ponderosa pine, sugar pine, Douglas-fir, incense-cedar, white fir, and red fir were examined on the westside Sierra Nevada.
2. Most of the living stumps followed logging but two occurred where the original tree was wind-felled.
3. Wood laid on after felling differentiates into heartwood and sapwood.
4. The oldest stump observed had persisted for 87 years; the tallest was 9 feet.

5. Original crown class does not govern the possibility of a root-grafted stump remaining alive.

6. Living stumps may serve a useful function in providing extensive root systems to residual members of the grafted cluster and in slowing the tree-to-tree spread of root rots.

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GROWTH FORM OF CRESTED WHEATGRASS AS AFFECTED BY SITE AND GRAZING¹

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INTRODUCTION

Growth characteristics within a species vary widely in response to variations in environment. Not only does the plant environment in a mountainous country change abruptly with elevation, but it also varies locally from site to site, depending primarily upon microrelief, slope and exposure, nature and depth of soil, and particularly on the supply of moisture. Clark (1945) concluded that a marked variability in the growth characteristics of range grasses was the rule rather than the exception.

Many investigators have studied height-weight or height-volume relationships of grasses as a basis for determining production or utilization (Campbell and Crafts 1938, Collins and Hurtt 1943, Crafts 1938, Lommasson and Jensen 1938, Lommasson 1943, Reid and Pickford 1941, and Valentine 1946). Various graphs,

conversion tables, and slide rules were developed from these relationships as aids in converting stubble height directly to utilization percentages. At first, the method met with notable success because of its simplicity and relative speed. But later on, several investigators pointed out a principal weakness in the method, mainly that variation in the growth characteristics of a species make data collected in one area useless in another (Clark 1945, Heady 1950, McArthur 1951, and Heady 1957).

The term "growth form" in this paper refers not to a height-weight relationship alone—as the word has been used in the work with forage production and utilization—but to the actual shape of the aerial or above-ground part of the grass plant in the field. Thus, the growth form of a crested wheatgrass³ plant describes the divergence from the perpendicular of the aerial canopy and may be defined as being erect, semispreading, spreading or prostrate. Variations are readily observed and appear to be influenced by past intensity of grazing and by differences in environment. This complicates the task of developing methods for estimating weight of herbage produced and degree of utilization based on individual plant measurements.

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³ Crested wheatgrass refers to *Agropyron desertorum* (Fisch.) Schult. The U. S. Department of Agriculture's Committee on Plant Nomenclature recommended on March 27, 1956, that *A. desertorum* be designated as crested wheatgrass and *A. cristatum* (L.) Gaertn. as fairway wheatgrass.