Annual Variability in Indicators of Sprouting Potential in Chamise

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The management of chaparral vegetation on ranges often is directed toward the encouragement of sprouting to provide browse or the control of sprouting during the conversion of the brush cover to grass. In either case an understanding of sprouting behavior is needed. Chamise *(Adenostoma fasciculatum)* is a sprouting species and a major component of extensive areas of chaparral in California.

In a previous paper Jones and Laude (1960) established relationships between sprouting potential in chamise and the level of starch reserve in the roots or of twig moisture at the time of cutting. It was recognized, however, that successful use could not be made of such factors for the indication of sprouting potential until the amount of annual variation in these seasonal trends in response to environmental conditions was established. The current study considers this annual variability over a period of four years.

Most studies of seasonal variations in stored reserves cover only a single year with the result that annual variations are not apparent. However, Winkler and Williams (1945) presented data on starch reserves in the roots of grapevines for two successive autumns, and found that whereas the percent starch was 18.5 percent on November 6 of one year it was only 6 percent on the same date the next year. They attributed the low level of the second year to early frosts which defoliated the plants thereby terminating assimilation and to the heavier crop produced the preceding summer. Obviously, stored reserves cannot be anticipated by calendar date alone.

The effectiveness of spray treatments on chamise in Southern California has been found to vary with the year.[1] Spraying near the end of the spring growing season has given the best control of first-year sprouts, but it was reported that more satisfactory results were obtained in 1958, a season favorable for chamise growth, than in 1959, a dry year.

Seasonal behavior of chamise must be considered in terms of the evergreen habit of the species when growing in areas of dry summers and relatively mild winters. Watkins and de Forest (1941) related the growth of chamise in Southern California to environment, particularly to the factors of temperature and moisture. They noted that shoot elongation may occur at two seasons. The primary period of growth is in the spring, although a secondary period of lesser activity may occur in the autumn. Both are characterized by variability from year to year in time of arrival and duration. They observed that elongation of stems ceased when air temperatures reached a minimum of 45° F.

Data are lacking on the extent to which temperatures or drought regulate the accumulation of stored reserves in chamise, but studies on other woody species provide some information. Hepting (1945) reported that in shortleaf pine (*Pinus echinata*) growing in Alabama and North Carolina, food reserves of the stem held constant during the winter, whereas root reserves, mainly starch, increased steadily all winter and reached a peak in early spring. Rutter (1957) observed that *Pinus sylvestris*, growing under mild winter conditions in England, increased in dry weight during the winter although the net assimilation rate at this season was much lower than in the summer. Low rates of assimilation were associated with summer drought. Kramer (1957) reviewed work on soil moisture in relation to photosynthesis in trees. He reported that photosynthesis was reduced by decreasing soil moisture considerably before the permanent wilting percentage was reached, and that after wilting, photosynthesis fell to extremely low levels.

Although the extent to which temperatures control assimilation in chamise during the winter is uncertain, it appears probable that the winter temperatures encountered in California are seldom low enough to prevent it altogether. Freeland (1944) studied photosynthesis in conifers during the winter in Illinois, and found that photosynthesis exceeded respiration at air temperatures above 21° F. Bourdeau (1959) noted in Scotch pine that although net photosynthesis was reduced to near zero by lower temperatures, that when the plants were brought indoors from winter conditions, photosynthesis started to increase after two or three hours. In less than 48 hours, photosynthesis in all the trees brought indoors exceeded respiration. It seems reasonable to expect that when moisture is available chamise will carry on appreciable photosynthesis and will accumulate stored reserves during the milder portions of winters in California.

Procedure

The plots were located in a natural stand of chamise on the University of California's Hopland Field Station at an elevation of about 3000 feet. The

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[1] *Fuel-break report No. 6, September 30, 1960, California Department of Natural Resources, et al.*

Table 1. Temperature and rainfall for the period of study.

	1956-57			1957-58			1958-59			1959-60		
		Temperature °F			Temperature °F			Temperature °F			Temperature °F	
Month	Rain (inches)	Mean min.	Mean max.	Rain (inches)	Mean min.	Mean max.	Rain (inches)	Mean min.	Mean max.	Rain (inches)	Mean min.	Mean max.
Aug.	......	....	....	0.00	57	81	0.00	69	92	0.00	70	88
Sept.	0.02	....	....	5.52	56	77	0.00	61	85	2.41	53	75
Oct.	1.81	48	62	7.10	44	61	0.41	53	76	0.15	52	73
Nov.	3.17	49	64	2.52	39	54	2.48	43	58	0.09	45	66
Dec.	1.01	38	55	7.32	35	49	2.16	45	60	2.36	35	54
Jan.	7.54	25	37	7.95	38	48	12.39	36	48	9.95	29	37
Feb.	8.48	35	47	20.76	38	46	9.39	32	45	9.58	31	46
Mar.	6.48	32	48	11.76	30	42	2.77	40	58	8.72	38	54
Apr.	3.67	38	61	6.04	40	57	0.68	45	66	2.34	35	53
May	5.32	42	58	0.96	47	70	0.16	43	65	2.55	41	59
June	0.00	56	80	1.60	49	71	0.00	57	81	0.00	59	85
July	0.00	61	84	0.00	66	86	0.00	70	96	0.00	68	92

methods of taking weather records, soil moisture and sprouting measurements, root and twig samples, and of making the chemical analyses were described in a previous paper (Jones and Laude, 1960). Data covered the period January, 1957 to July, 1960. At each date of sampling starch analysis of root tissue was made on six chamise plants subject to moderate browsing by deer and rodents in an unfenced area. However, whereas three plants were pooled to give duplicate samples in 1957 and 1958, six plants were analyzed separately at each sampling date in 1959 and 1960.

In addition to measuring growth by the rate of elongation of tagged shoots, the width of annual rings in stems was observed. For this purpose stems ¼ to ⅜ inch in diameter were collected from 50 plants on March 2, 1961, before spring growth commenced. The stems were killed and fixed in Randolph's fluid. Sections 40 microns in thickness were cut for study under the microscope.

Results and Discussion

The annual variability in the time of greatest starch accumulation in the root, in the maximum amount of starch stored, in the date of initiation of new spring growth, and in the date of highest twig moisture becomes apparent when results of the four years are compared. Fortunately, plant behavior for 1957 and 1958 was approximately "normal." Table 1 presents the temperature and rainfall values. The irregularities of the 1958-59 and 1959-60 seasons relate primarily to the dry periods which occurred each autumn, and these will be discussed in more detail later.

The significance of differences in starch level during the first two years is shown in Table 2. High levels occurred in the spring, lower levels prevailed in mid-summer and gradual increase was noted in the autumn. Such a consistent trend did not occur in 1959 and 1960 (Table 3). During the spring of 1959 no build-up in starch reserves was recorded, and the most significant decrease of that year was obtained in December. In 1960 the highest level was not reached until May, although the mid-summer low did appear. These data establish a considerable variation in pattern over successive years. An explanation of this variability can be attempted in terms of moisture, temperature, and growth responses.

In considering seasonal behavior of chamise it is appropriate to relate consecutive fall, winter, and spring periods which cover the annual growth cycle rather than to use the calendar year. Growth activity in this species starts in the autumn

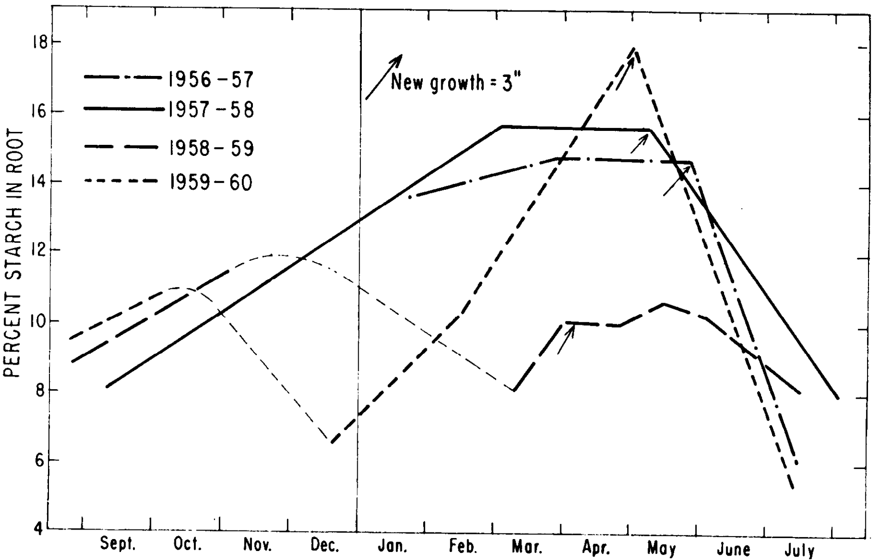

FIGURE 1. Starch trends in chamise roots.

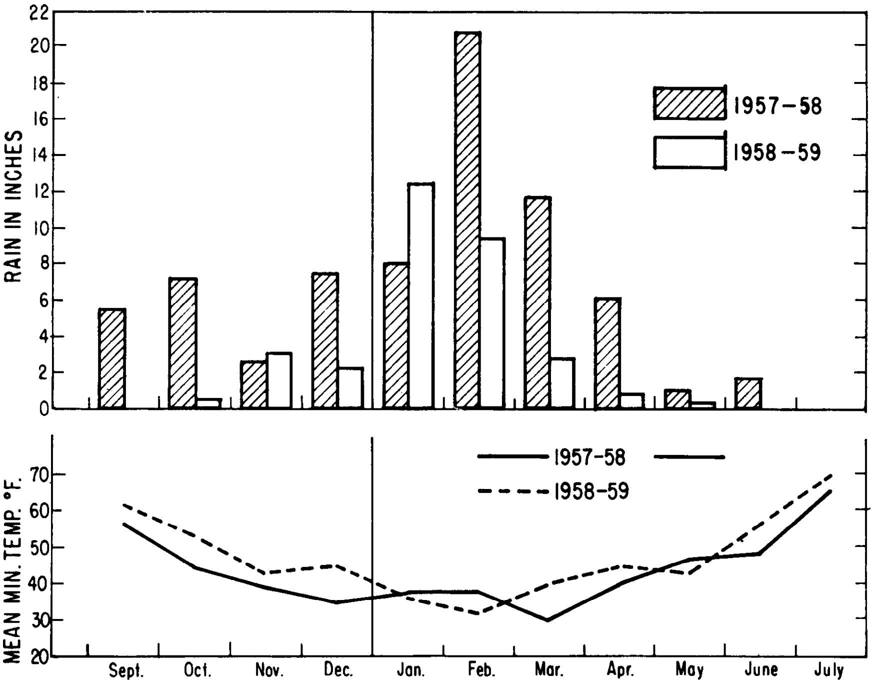

FIGURE 2. Comparison of rainfall and temperature for two seasons in which chamise differed in starch reserves.

when rains commence before temperatures drop. Stored reserves accumulate overwinter reaching a peak in early spring. The primary period of shoot elongation is between April and June when starch reserves become rapidly depleted. Although it is possible for a growth period of secondary importance to occur in the fall (such was noted by Watkins and de Forest, 1941), we detected only meager shoot elongation at this season at Hopland.

Figure 1 presents the levels of starch reserves in root tissue during the four years. The arrow on each curve depicts the date by which new spring growth had attained a length of 3 inches on the majority of shoots. This date marks the beginning of rapid starch depletion in the 3 years when winter accumulation was considerable. It also indicates the date of greatly increased twig moisture. During late winter this moisture was about 65-80 percent on a dry weight basis in the terminal several inches of the past season's growth. When new shoots appeared in the spring, they possessed a moisture content of 140-160 percent. By the time these new shoots reached lengths of 10-12 inches available soil moisture to a depth of 4 feet was virtually exhausted. Under this stress of dryness which continued over summer and resulted in a proportion of the leaves being shed, the new growth was incapable of contributing appreciably to starch reserves. If autumn rains came early while temperatures were still warm, carbohydrate synthesis and storage commenced and the ability of the plant to sprout after treatment was increased. The light-dashed segments on Figure 1 indicate intervals during which expected increase in starch reserves did not occur. In 1959-60, weather conditions at this period delayed the normal winter build-up, but did not prevent it. Although 2.41 inches of rain came in mid-September, it was largely ineffective due to the warm dry period that followed. Precipitation in October and November totalled only 0.24 inch and temperatures remained relatively high. By the time substantial rains did commence in December, temperatures were low enough to prevent shoot elongation. This condition prevailed until early May, resulting in a 5-month period conducive to assimilation and reserve storage.

The situation in 1958-59 was more complex and prevented reserve accumulation in the roots. September and October, 1958, were the warmest and driest of the four years. By early November a considerable amount of shoot dieback was observed, and occasional plants died. Except for a single cold week in mid-November, the weather remained relatively warm until January. By March temperatures again rose and the driest spring of the four years prevailed. Growth started early, producing 3-inch new twigs by April 4, a month before such was recorded for the other years. By May 14 the soil

Table 2. Percent starch in chamise roots during two years of relatively normal rainfall distribution.

Date of cutting	Starch in root (Percent)	Significance at 5 percent level Duncan's Test		
1957				
Jan. 24	13.60	a	b	
Mar. 27	14.80	a		
May 27	14.75	a		
July 15	6.10			c
Sept. 10	8.05		b	c
Nov. 19	11.05	a	b	c
1958				
Mar. 4	15.70	a		
Aug. 5	8.00		b	c
Nov. 6	11.50	a	b	c

Table 3. Percent starch in chamise roots when influenced by draught periods.

Date of cutting	Starch in root (Percent)	Significance at 5 percent level Duncan's Test			
1959					
Apr. 2	10.10		b		
Apr. 23	10.00		b		
May 14	10.63		b		
June 4	10.33		b		
July 14	8.18		b	c	
Sept. 24	10.50		b		
Dec. 18	6.55			c	d
1960					
Feb. 17	10.43		b		
May 2	18.08	a			
July 12	5.43				d

was dry to a depth of 4 feet, again earlier than in other years. Figure 2 compares 1957-58 with 1958-59 in regard to rainfall and minimum temperatures, and illustrates the warm dry autumn and spring of the latter season. It is suggested that failure of root starch to accumulate can be attributed to the shortened winter period when net assimilation was not offset by utilization through growth. It is interesting to note that Fuel-break report No. 6 (previous citation) referred to the poor results obtained by spray treatments in Southern California in the spring of 1959 compared to 1958.

Width of annual rings in the secondary xylem was investigated for the four years of this study. The stems sectioned were from plants which had been burned in 1946, so 8 or more rings were detected on most of the samples. For the first 3 or 4 years the growth increment was measurable in terms of secondary xylem deposition. However, the later rings which corresponded to the years of our study were so indistinct and variable that they did not yield useful measurements. Watkins and de Forest (1941) reported extreme irregularity in the amount of elongation among chamise stems. Annual ring variability likewise reflects a lack of uniformity in growth among shoots.

These experiments indicate that chamise normally enters a period of physiological "weakness" in the late spring and early summer when starch reserves are at a minimum. The date of this period will vary somewhat from year to year but follows the onset of new spring growth by 4 to 6 weeks. Shoot regrowth the year following cutting treatments applied at this period was reduced (Figure 3, Jones and Laude, 1960).

It is reasonable to expect that the effectiveness of treatments to control chamise may be enhanced by timing the treatment during the period of low stored reserves following winters of relatively substantial starch accumulation in the roots.

Summary

The annual variability in chamise growth and in starch reserves in the root was related to environmental conditions over a four-year period. The starch trend, date of growth initiation, and twig moisture level varied sufficiently in relation to prevailing moisture and temperature conditions as to render unreliable the scheduling of control treatments by calendar date.

Reduced vigor of sprouting is associated with treatments applied in the late spring and early summer when the high winter and early spring level of root starch reserves has been depleted. This period of low starch follows the onset of spring growth by 4 to 6 weeks. It is suggested that the effectiveness of treatments to suppress chamise would be increased by scheduling them during this period of low stored reserves.

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