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GROWTH AND REPRODUCTION OF BITTERBRUSH IN CALIFORNIA

[1942, SEPT]

[By A.L. Hormay]

CONTENTS

	Page
Introduction	1
Description of bitterbrush	2
Detailed description	2
Mature plant	2
Fruit and seed	3
Seedling	4
Habitat	5
Growth and development	6
Mature plant	6
Seedlings	7
Stems	8
Reproduction	9
Role of rodents	9
Rodents plant bitterbrush seed	10
Rodents plant bitterbrush stands	12
Effect of grazing and defoliation	17
Grazing by livestock	17
Grazing by deer	21
Defoliation by caterpillars	22
Effect of burning	24
Artificial reseeding	26
Selection of seed	27
Depth of plant and ground preparation	27
Time of planting	28
Method of planting	28
Intensity and coverage of planting	30
Summary	31
References	33

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GROWTH AND REPRODUCTION OF BITTERBRUSH IN CALIFORNIA

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INTRODUCTION

Bitterbrush (Purshia tridentata D. C.) is one of the most valuable browse plants on western ranges. Its general distribution covers about 340,000,000 acres in 11 western states and southern British Columbia (fig. 1). It is a very palatable and nutritious shrub and is generally closely grazed by cattle, sheep, and goats and also by deer, and other game animals. Its seeds are an important item in the diet of several rodents that are of economic importance on the range.

In California bitterbrush is the most important range browse on approximately 7,500,000 acres east of the Sierra Nevada and Cascade Mountains (fig. 1). Here many valuable bitterbrush stands have been killed out or are being deteriorated by such factors as improper grazing, fire, defoliation by caterpillars, activities of rodents, and other influences. Furthermore there is not enough bitterbrush reproduction on many ranges to permit perpetuation of the stand. These conditions represent a serious loss in livestock production.

Few specific studies have been made of bitterbrush in spite of its importance and wide distribution. Some experiments were made on the medicinal value of the plant by Trimble ('92) who made a chemical analyses of the fruit, and by Netz, Rogers and Jenkins ('40) who made chemical and histological studies and tests of the curative action of fluid extracts from the plant. Forsling and Storm ('29) pointed out the harmful effect of close grazing on this plant in a study with cattle in Utah. Dixon ('34) observed the utilization of bitterbrush by mule deer in California. Entomologists have studied the effects of Great Basin tent caterpillars on the plant.

FIG. 1. General distribution of bitterbrush in California (A), and the United States and southern British Columbia (B).

Sampson ('24), Dayton, et al ('37), and others have described bitterbrush and pointed out some of its range characteristics.

However, more information was needed for the proper management of this plant. For this reason experiments and observations were started on several bitterbrush ranges in northeastern California in 1940. The first results of this work are presented in the following paper. Many of the findings may be applied outside of California.

DESCRIPTION OF BITTERBRUSH

Bitterbrush (fig. 2) is a straggly branched, grayish-green shrub 1 to 5 feet high with fascicled, 3-toothed, wedge-shaped leaves 1/2 to 3/4 inches long. Its numerous yellow flowers have 5 petals and many stamens. Bitterbrush is known under several other common names including quinine-brush, deer-brush, buckbrush, antelope-brush, greasewood, and black sage. The names bitterbrush and quinine-brush are quite appropriate because all parts of the plant, even the flowers and wood, have a very bitter taste.

Detailed Description

Mature plant. Diffusely-branched, grayish-green, deciduous shrub 1½ to 5 feet high, rarely reaching 16 feet; stems above root crown 1 to 4 inches in diameter sometimes reaching 12 inches, the basal portions with numerous adventitious buds; plant anchored by a sparingly branched, reddish-brown tap root; bark on older stems and branches coffee brown, shreddy and exfoliating in thin layers, on young branches silver gray, reddish brown when wet, smooth; current year's twigs usually glandular below tip, felty, covered with white matted hairs, the covering splitting on lower portion of twig; branches emerging from three sides of the stem one above the other; leaves fascicled, wedge-shaped 6 to 20 mm. long, 3-toothed at apex, set on

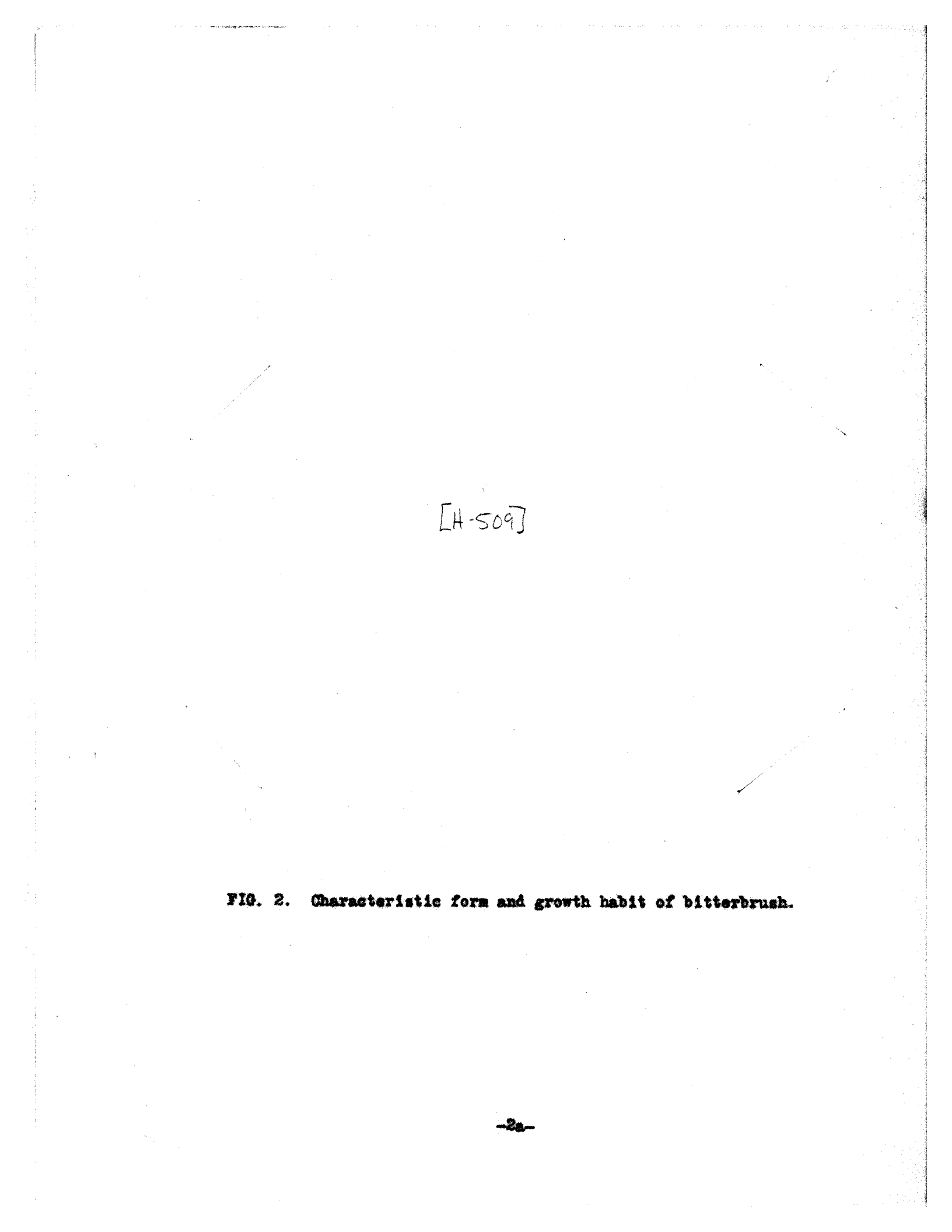


FIG. 2. Characteristic form and growth habit of bitterbrush.

short petioles with stipules, margins slightly turned under, edges and veins on under surface usually with glandular hairs, upper surface thinly hairy, dark green to light gray green, under surface densely matted with hairs, gray green to almost white; flowers, usually accompanied by one or two young growing shoots, set in a fascicle of leaves; petals 5, pale yellow, 6 to 10 mm. long, 4 to 5 mm. wide, the tapered end attached to top of calyx tube by a slender claw about 2 mm. long; stamens about 25 slightly shorter than the petals, attached in a single row to top of calyx tube; calyx densely hairy and frequently glandular on the outside, not hairy or glandular on the inside, the tube funnel shaped 3 to 5 mm. long set on a short stem 3 to 5 mm. long; ovary one and sometimes two in each flower, 1 celled, enclosing a single ovule, stigma placed on one side of the curved beaked style.

Fruit and seed. Fruit (fig. 3L) a spindle-shaped, conspicuously ribbed, hairy achene, 10 to 15 mm. long. Seed (figs. 3M and 4) dark-purplish brown to black, sometimes grayish or mottled with gray, 5 to 8 mm. long, slightly flattened, egg-shaped, tapering to a point on one end, outer seed coat hard, thin, white and relatively transparent; embryo white consisting of two large oval-shaped cotyledons and a conspicuous pointed rootlet directed toward the tapered end of the seed, enclosed in a thin white sac; endosperm (the tissue between the seed coat and the sac around the embryo) crystalline, granular, deep purplish-red.

FIG. 3. (a,b,c,d) Bitterbrush seedling in different stages of growth from germination to 1 month old; (e) cotyledon ventral surface; (f) leaf ventral surface; (g) leaf dorsal surface; (h) portion of hypocotyl showing glandular hairs; (i and j) glandular hairs; (k) slender rootlet; (l) fruit; (m) seed.

FIG. 4. (A) Section through fruit showing position of seed inside ovary wall (pericarp); (B) seed, showing hilum the point of attachment of seed to pericarp; (C) embryo, lateral view, showing cotyledons and rootlet (radicle); (D) embryo, dorsi-ventral view, one cotyledon removed to show first leaves and shoot (plumule).

Seedling. (fig. 3). Cotyledons 6 to 10 mm. long, 5 to 6 mm. wide, on short pedicels 1 to 2 mm. long, wedge-shaped, the base with two pointed lobes, tip broad, slightly indented, edges and sometimes lower part of upper surface with gland-tipped hairs, otherwise smooth; stem (hypocotyl) usually 20 to 30 mm. long, conspicuously reddish-purple and covered with reddish gland-tipped hairs for distance of 10-15 mm. below cotyledons; young leaves densely hairy, felty; the top surfaces less hairy than the under surfaces; edges, teeth, and midribs of under surface with gland tipped hairs; first and second leaves 3- to 4-toothed along margins, the third and fourth toothed on upper third of leaf only, usually the fifth and succeeding leaves 3 toothed at apex.

Bitterbrush plants grade from silver-gray to dark green in color. These differences are due primarily to the hairiness of the leaves. The leaves on the grayish plants are densely covered with white hairs on both surfaces and are sprinkled lightly with resinous gland-tipped hairs on the margins and veins of the under surfaces. On the greener plants the leaves are frequently smaller and much less hairy; the upper surfaces being almost smooth in some cases. They are densely covered with pustulate glands as well as glandular hairs, which gives the plants a strong and somewhat obnoxious resinous odor. Some of these color variations no doubt represent varietal differences, since sharply contrasting forms may be found growing side by side in the same environment. In some localities the lighter-colored plants appear to be grazed less by livestock than the darker ones, perhaps because of the greater hairiness.

The stems of bitterbrush are woody. The wood is hard and brittle. The sapwood is white in the living plant and turns deep yellow when the stems are cut and exposed to the air. The yellow coloring, which may have value as a dye is less intense in the dried wood. The heartwood is reddish brown.

The stems show definite annual growth-rings. The spring wood is characterized by the presence of a large number of conspicuous pores which are smaller in later wood and are replaced completely by a compact mass of fiber cells in the wood formed in late summer. Contrasts in color and structure of the cells between summer and spring wood permits differentiating one growth ring from another in most thrifty plants.

HABITAT

In California bitterbrush is found at elevations from about 3,000 to 9,000 feet. The average annual precipitation on some areas where it grows is as low as 10 inches and on others it reaches 45 inches. About 80 percent of the precipitation on bitterbrush range falls from November to April mainly in the form of snow. The plant survives temperatures from -35° to 110° Fahrenheit.

Bitterbrush grows on sites occupied by big sagebrush (Artemisia tridentata), Sierra juniper (Juniperus occidentalis) and ponderosa and Jeffrey pine (Pinus ponderosa and P. Jeffreyi). The densest and more vigorous stands are found in pine forest openings and on sagebrush lands bordering the open-pine forest. The plant most commonly associated with bitterbrush is big sagebrush.

Bitterbrush flourishes on most types of light, well-drained soils. Some of the largest and fastest-growing plants are found on fine-textured volcanic soils and also on coarse sandy granitic soils.

Bitterbrush usually found on fairly deep soils. I believe it requires fairly deep soil.

GROWTH AND DEVELOPMENT

Mature Plant

The seasonal growth and development of bitterbrush varies in different localities depending on elevation, weather, and other conditions. In a particular locality growth progresses generally as follows:

The young leaves, which are enclosed in the same bud with the undeveloped flower, emerge in late April or early May and grow to full size in two to three weeks. By the time leaf growth is completed the small round grayish flower buds become evident and some of them start to open in late May or early June. Mass flowering follows shortly and lasts for a period of about 20 days ending in the latter part of June. These flowers are borne on the previous year's twig growth.

Current twig growth starts at about the peak of flowering and ends 1½ to 2 weeks later in the middle of September. Many of the twigs send out lateral shoots. The period of most rapid twig growth is during the month of July. Apparently radial growth in the main tap root and stem start before twig growth is initiated since more than half of the annual increment is often formed in the main root and stem before twig elongation starts.

The seeds mature in late July or early August before twig growth is completed. Practically all of the heavier viable seeds drop from the plants during a period of about a week. The endosperm in the seed develops a deep purplish-red juice about 1 month after pollination of the ovary. The seed ripens in about 2 to 3 weeks after this red juice becomes evident.

Bitterbrush sheds its leaves in September or October when soil moisture reaches a low level or freezing temperatures set in. In some years the leaves drop off earlier in the season, probably in response to drought conditions. Only the blades of the leaves fall off. The short petioles with their two-pointed stipules remain attached to the branches. By November,

the leaves are practically all cast and the plant passes through the winter in this condition.

The progress of growth of bitterbrush in a specific locality is shown in Table I.

TABLE I. Growth and development of bitterbrush, 1942
Hall's Flat, Lassen National Forest

Stage	Month							Growth period
	May	June	July	Aug.	Sept.	Oct.	Nov.	
1. Leaves growing	xx							May 8 - 20
2. Flowering		xxx						June 1 - 20
3. Twigs growing		xxxxxxxxxxx		xxxxxx				June 10 - Sept. 15
4. Seeds ripe and falling				xx				August 1 - 10
5. Leaves falling					xxxxxxxxxxxxxxx			Sept. - Nov.

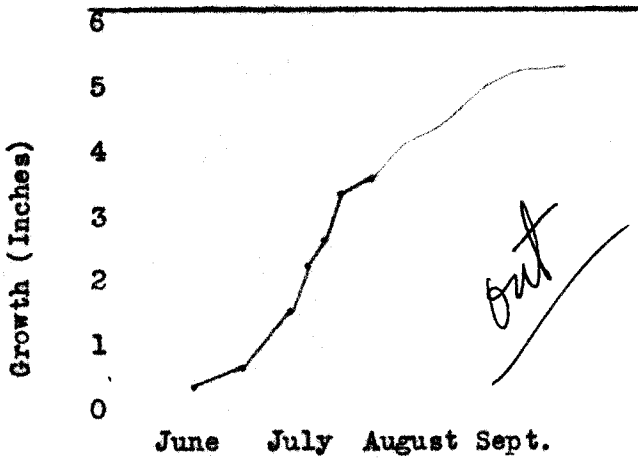


FIG. 5. Growth of twigs on bitterbrush at Hall's Flat on the Lassen National Forest, 1942.

(See page 7a)

Seedlings

The seedlings of bitterbrush germinate in the spring when the parent plants start to grow. The cotyledons are raised 1 to 2 inches above the soil surface on the growing hypocotyl. By the end of the first month, 6 to 7 leaves and one-half to one inch of stem growth are produced above the cotyledons, and the roots are 6 to 8 inches long.

Bitterbrush provides bulk and nutritious forage for livestock and game animals. A bitterbrush stand of 0.2 density will yield about 900 pounds of forage per acre in an average year. This figure is based on a measured average yield of 47.6 grams per square foot of crown area at the Burgess Spring Experimental Range on the Lassen National Forest in 1936. The yield of bitterbrush is closely related to the length of twig growth which ranges from 2 to 3 inches in poor growth years to 10 to 12 inches in the most favorable years. The twig growth at Burgess Spring in 1936 averaged 7.5 inches.

The stems rarely exceed 2 to 3 inches in height at the end of the first growing season. The roots, however, get to be 15 to 20 inches long. Lateral branching of the stem usually starts in the second year or sometimes in the first when the seedlings have been grazed.

Flowering and seed production start around the fourth or fifth year of growth on some sites and a few years later on other sites (table II). Appreciable seed production cannot be expected in most localities before the tenth year. The youngest flowering plants are 8 to 12 inches wide and 10 to 16 inches high.

TABLE II. Youngest bitterbrush plants producing flowers and seed.

Age	Location	
	Portola	Truckee
Years	Number	Number
1	0	0
2	0	0
3	0	0
4	8	0
5	9	1
6	6	2
7	2	8
8	1	0
9	1	4
10	0	5
11	0	2
12	0	3
13	1	1
	28	26

NOTE: Samples were taken from the smallest bitterbrush plants in the stand that produced seed.

Stems

Dominant, vigorously-growing bitterbrush plants produce one growth ring a year (table III). In rapidly-growing plants the growth rings often exceed 1/8-inch in width. The age of most dominant plants can be determined

TABLE III. Correlation between the known age and the number of annual rings in the stems of dominant bitterbrush plants

Cases	Age	Annual rings
Number	Years	Number
1	10	10
1	10	11
11	11	11
2	11	10
1	12	12

by counting the annual rings. A 6- to 10-power hand magnifier will serve for this purpose. Bitterbrush reaches 80 years of age. The average age at death is probably between 50 and 60 years.

Accurate age determinations cannot be made on all plants for several reasons. (1) Growth rings are not formed in some plants in certain years or may be so suppressed that they can not be seen. (2) Portions of the bases of the stems frequently decay from accumulations of soil and litter in the lower crotches and some of the growth rings are destroyed. (c) Bitterbrush commonly develops irregular-shaped stems (fig. 6). In some cases the first growth rings lie on one side of the stem instead of near the middle and are exposed to destruction through weathering, abrasion, and decay (figs. 6B, D, E). The older stems are the most irregular and eccentric.

The best place to section the stem for ring counts is just above the root crown and below the point where the main stem starts flaring into the branches, for all growth rings are present at this point.

For many practical purposes stem size may be used to gage the relative ages of bitterbrush plants on a given site (fig. 7). The correlation between stem size and age is rough because of differences in shape of stem and width of annual rings of plants growing under different conditions.

REPRODUCTION

Bitterbrush reproduces essentially from seed. It has been observed to sprout from some of the numerous buds located near the base of the main stems following injury or removal of the crown by fire, or mechanical means such as chopping or crushing (fig. 8). Some plants become established by layering, that is by the rooting of older branches that touch the ground (fig. 9). Sprouting and layering occur infrequently, however, and are not important in the propagation of bitterbrush in California. Measurements and widespread observations have shown that in California bitterbrush stands

FIG. 6. Cross sections showing shape of bitterbrush stems. The white dot marks the location of the first growth rings. (A) Symetrical growth, thin sapwood, (B, D, E) Irregular one-sided growth, limited sapwood, (C) Rapid-growing stem, thick sapwood.

FIG. 7. Relation between stem diameter and age of bitterbrush.

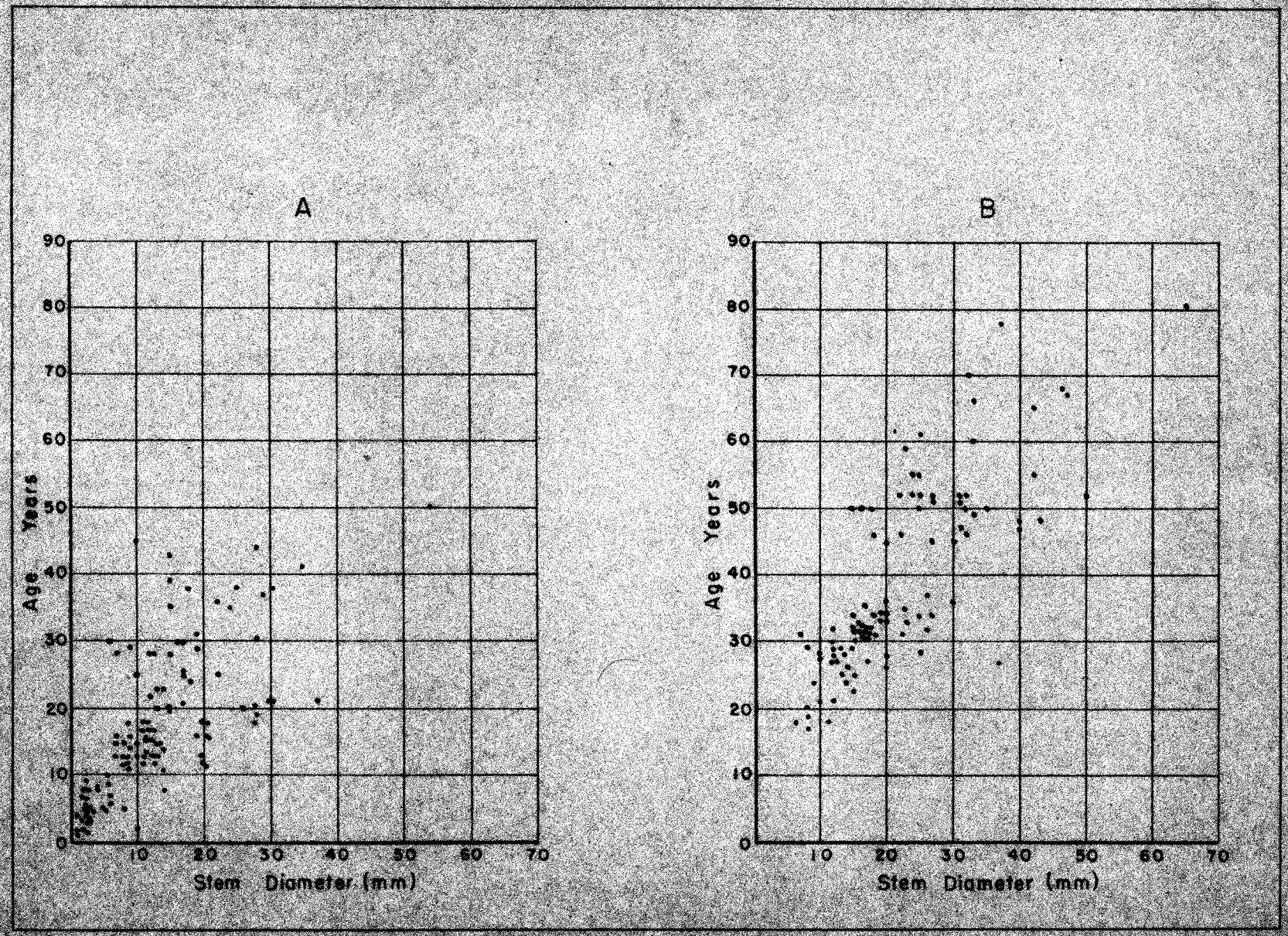


FIG. 7. Relation between stem diameter and age of bitterbrush.

FIG. 8. Resprouting of bitterbrush following burning is rare in California.

FIG. 9. Bitterbrush rooting from a branch that touched the ground.

become established mainly from seeds planted by rodents.

Rodents Plant Bitterbrush Seed

Rodents bury caches of bitterbrush seed from 1/2 to 1½ inches deep in the soil. The seeds in these caches germinate in the spring to form clusters of seedlings (fig. 10). As many as 80 seedlings have been found growing from a single seed cache. Observations show that all of the seeds in the caches do not germinate so it is likely that as many as 100 are planted in the larger ones. A tuft of germinating seedlings may be easily mistaken for a single bitterbrush plant several years old. This may have led some observers to overlook bitterbrush seedlings when they were actually present.

The amount of caching done by rodents from year to year no doubt depends on the amount and quality of the seed produced, its value as food to the rodent compared to other available food and other factors. Some bitterbrush seed is probably planted in most good seed-production years (table IV). In the poorer years the scant seed supply may all be eaten by rodents.

Seed caching by rodents was very heavy throughout northeastern California in 1940. In contrast it was very light in 1941. The number of germinating seedling clusters found on experimental plots in 1941 averaged around 150 per acre. Small areas usually not more than 100 to 200 feet in diameter, apparently centers of heavy seed supplies and concentrated rodent activity, are planted more densely than the surrounding range. An area 50 feet wide and 66 feet long on one of these sites near Browns Well on the Modoc National Forest contained more than 100 caches of the same age (1941 germination) (fig. 11). This represents a population of about 1300 caches per acre. A plot fenced against grazing on the Lassen National Forest contained over 72 caches on an area 100 feet wide and 132 feet long. Rodents do not replant the same areas intensively year after year since there is no evidence that

A B

FIG. 10. (A) A cluster of bitterbrush seedlings germinating from a rodent seed cache. (B) The seedlings (shown in A) partly excavated and spread out to show numbers. Notice the cotyledons on the seedlings.

FIG. 11. The stakes mark the location of bitterbrush seedling clusters derived from rodent seed caches. The plantings were exceptionally abundant on this limited area in this year.

the mature stand is more dense or is represented by a larger number of age classes in one place than another. (continued on page 11_1)

TABLE IV. Age and number of groups of bitterbrush plants in the stand originating from seed cached by rodents.

Bear Wallow Mountain, Lassen National Forest, 1941

Caches		Caches	
Age	Number	Age	Number
1	5	24	
2	2	25	1
3		26	
4	1	27	
5	3	28	
6		29	
7	1	30	
8	1	31	
9		32	
10	1	33	
11		34	
12		35	
13	3	36	
14		37	
15	1	38	3
16	2	39	
17		40	
18		41	2
19		42	
20	1	43	
21	1	44	
22		45	2
23			

NOTE: Many of the single plants in the stand were part of rodent caches in previous years. Because these could not be identified, they could not be entered in the table.

During the summer and fall evidence of the eating of bitterbrush seeds by rodents is found almost everywhere. Hundreds of seed coats can be found on rocks, stumps and logs (fig. 12). Chipmunks have been observed eating bitterbrush seed when it is in the red juice stage. This sticky red juice which resembles blood to a remarkable degree gets on the feet of the

If the average age of bitterbrush at death can be assumed to be 60 years and the population of the average stand to be 2500 plants per acre, which is the average of several stands studied, the establishment of about 42 rodent caches per acre per year on the average would be sufficient to maintain the bitterbrush stand.

FIG. 12. Remains of bitterbrush "seeds" on top of old stump.

FIG. 13. The red juice of bitterbrush seed smeared on rock and branch by rodents.

chipmunks. It may be found smeared on rocks, sticks, logs, stumps, fence posts, the stems of shrubs and even branches of pine trees 5 to 6 feet above the ground (fig. 13). The amount of tell-tale red juice found on objects in bitterbrush stands roughly indicates the amount of rodent activity and the amount of seed produced during the season.

Rodents show some preference in planting sites. Soft, loose, or recently disturbed soils such as road shoulders, road banks, borrow pits, and areas disturbed by logging are favored. The deep duff and litter at the base of pine trees is a preferred planting site. Bitterbrush seedlings may be found here when they cannot be located elsewhere in the vicinity. Bitterbrush seedlings from rodent seed caches have been found in all types of soils on which bitterbrush has been observed to grow.

The planting of bitterbrush seed by rodents has not been directly observed, although chipmunks and golden mantel ground squirrels have been seen to dig into the base of germinating seedling groups in the spring of the year. The rodents believed to be primarily responsible for the caching of bitterbrush seed are chipmunks (Eutamias), golden-mantled ground squirrels (Citellus lateralis chrysodeirus, Merriam), and probably mice (Peromyscus). The limited distribution of the digger squirrel (Citellus douglasii Richardson) in bitterbrush areas rules out this rodent as a principal planting agent. The large number of seed in many caches and the depth of planting suggests that chipmunks and golden mantled ground squirrels do the bulk of the caching.

Rodents Plant Bitterbrush Stands

The most convincing evidence indicating that bitterbrush stands grow primarily from seeds planted by rodents is the presence in the stands of a large number, and sometimes a majority of crowns, which are made up of two or more plants. On one area where records were made, 58 percent of the crowns

consisted of two or more plants (table V). On four other areas the percentages were found to be 40, 23, 18, and 15. The lower percentages are correlated with closeness of grazing. Close grazing reduces the number of plants in the crowns.

TABLE V. Number of plants per crown in a lightly grazed bitterbrush stand, Lassen National Forest, 1941.

Plants per crown	Approximate diameter of stems of plants - inches							Total	Percent
	1/16	1/8	1/4	1/2	1	1½	2	2½	3	3½		
Number	Number of crowns											
1	13	8	3	7	12	6	3				52	42
2	1	3	4	6	9	2	2				27	22
3			5	2	2	2					11	9
4		1	2	3	4						10	8
5		1		2	4						7	5
6	1	2	2		2						7	5
7				1	1						2	2
8	1	1									2	2
9			1								1	1
10	1				2						3	2
11	1										1	1
17		1									1	1
Total	18	17	17	21	36	10	5				124	
Percent	15	14	14	17	28	8	4					100

The number of plants surviving in caches decreased with the age of the plants. All of the seedlings die the first year or two after germination in some caches. In others the number surviving range from one to many. Records taken in two locations show that at the end of the second year about 20 percent of the caches were represented by single seedlings (table VI). Many of the single plants in the mature stand therefore originate from rodent caches.

Only a small proportion of the stand becomes established from the seed that is not cached by rodents. This is indicated by the following observations. Bitterbrush seed is relatively heavy and is not provided with structures for widespread dissemination by wind or water. A few seeds get into the interspaces between the larger plants, probably by being brushed or

TABLE VI. Survival of bitterbrush seedlings[1/] in rodent caches.

Seedlings per cache	Brown's Well, Modoc Nat'l. Forest — Number of caches				Black's Mtn., Lassen Nat'l Forest — Number of caches			
	June 22, 1941	Oct. 13, 1941	May 1942	Sept. 1942	June 19, 1941	Nov. 12, 1941	June 1942	Sept. 1942
0		0	5			8	10	
1		10	13			6	6	
2	9	10	13		4	5	4	
3	8	7	10		3	4	9	
4	5	11	10		4	7	4	
5	9	9	11		6	7	6	
6	9	7	4		9	1		
7	8	5	3		2	9	8	
8	2	5	3		7	2	2	
9	5	7	2		3	1	2	
10	5	6	7		3	3	3	
11	7	3	4		2	3	4	
12	4	4	6		2	3	2	
13	6	2	1		6	2	2	
14	5	3	1		4	3	4	
15	1	2	3		6	3	2	
16	3	2					1	
17	2		1		3	1		
18	1	1			1	1		
19	2	1				2	2	
20	1				4			
21		2	1		1			
22								
23		1	1					
24	2		1		1			
25		1						
26	3							
27								
28	1				1	1	1	
29	1							
30		1						
.								
.								
.								
.								
45	1							
Total	100	100	100		72	72	72	

1/ Germinated in April and May, 1941.

carried there by livestock or other animals besides rodents, but most of them fall directly to the ground under the parent plants or within a few inches of their outer edges (fig. 14). The seedlings which germinate from these seed (table VII) do not survive for more than a few years in this environment probably because of shading by the parent plant and competition for moisture (table VIII).

TABLE VII. Location of germinating bitterbrush seedlings in relation to parent plants, Lassen National Forest, 1941.

	Area No. 1/ Location			Area No. 2/ Location		
	Interspaces between plants	Under parent plant	Total	Interspaces between plants	Under parent plant	Total
	Percent	Percent	Percent	Percent	Percent	Percent
Single seedlings	9	62	71	5	93	98
Rodent caches	19	10	29	1	1	2
Total	28	72	100	6	94	100

1/ Based on 21 seedlings.
2/ Based on 274 seedlings.

TABLE VIII. Location of bitterbrush reproduction of different size (age) classes in relation to the crowns of parent plants.

Average stem diameter	Location	
	Under plant crowns	Between plant crowns
Inches	Percent	Percent
1/16	89	11
1/8	59	41
1/4	18	82
1/2	5	95
1	6	94
2	0	100
3	0	100

Eighty-nine percent of the youngest plants with stems averaging 1/16-inches in diameter were found under or around the edges of parent plants, and only 11 percent were in the open between plants. On the

FIG. 14. Distribution of bitterbrush seed around the parent plant.

other hand 82 percent of the older plants with stems 1/4 inches in diameter were found growing in the open and only 18 percent were under the crown of the mother plants. Only 5 percent of stems 1/2 inch in diameter were under the parent plants and 95 percent were in the interspaces. This shows that most of the plants starting growth under or around the crowns of older plants die before they reach 1/2 inch in diameter. Some of the survivors are from rodent caches since rodents plant under the crowns of older bitterbrush plants (table VI).

Records indicate that seedlings from rodent-planted seed have about twice the survival rate of seedlings from unplanted seed growing under the same conditions. This may be due to the selection of the more viable seeds by rodents, and perhaps to depth of planting. Close inspection of several rodent caches showed that ~~the largest part~~ most of the planted seeds germinated. The planting of seed 1/2 to 1½ inches in the soil probably permits earlier root development which provides the seedling with sufficient moisture for survival during the summer.

The large number of seeds in most rodent caches more or less insures the germination of at least one vigorous seedling in the cache. The roots of some of the seedlings in rodent caches penetrate the soil more deeply than others and are the ones that finally survive. Deep root penetration and firm anchorage of the plant the first winter reduces the chances of the seedlings being heaved out by freezing and thawing during the winter and spring, which causes the loss of many seedlings.

The establishment of most of the bitterbrush stand from rodent-planted seed is largely explained then by (1) rodents plant the seed in the shrub interspaces which are more favorable for seedling growth than the area under the crowns where the seeds are cast naturally (2) rodents bury the seed 1/2 to 1½ inches in the soil which gives the seedlings a better

chance for survival (3) rodents apparently plant seed of greater than average viability (4) the large number of seeds per cache more or less insures the germination of one or more vigorous seedlings. These points have important applications in the artificial reseeding of bitterbrush which is discussed briefly later.

Rodents have been observed to destroy germinating bitterbrush seedlings and to girdle and kill some mature plants during the winter and spring, but on the whole their influence on the growth and reproduction of bitterbrush is overwhelmingly beneficial.

EFFECT OF GRAZING AND DEFOLIATION

Grazing by Livestock

Livestock grazing is perhaps the most important biotic factor influencing the growth and reproduction of bitterbrush. Both cattle and sheep graze this browse in all stages of growth.

Bitterbrush crowns assume characteristic shapes in response to grazing by cattle and by sheep. As a rule, cattle graze this browse more closely than sheep, utilizing not only current twig growth but also woody branches up to 1/4 inch in diameter. Cattle graze bitterbrush heavily on the top, so the plants acquire a strongly hedged, mushroom-like shape after a period of years (fig. 15). On most cattle ranges, bitterbrush is kept grazed down to a height of 1 to 2 feet which is well within reach of the livestock.

Sheep confine their grazing mainly to the current year's growth, frequently stripping off only the leaves and rarely utilizing the woody

FIG. 15. Characteristic shape of bitterbrush plants on cattle ranges.

FIG. 16. Characteristic shape of bitterbrush plants on sheep ranges.

growth of previous years. They do not top the plants as closely as cattle. The plants do not become strongly-hedged and mushroom-shaped like those on cattle ranges but maintain a semi-erect, straggly-branched form (fig. 16). Under moderate or even heavy use, several terminal shoots are usually left ungrazed on many plants on sheep ranges. These often grow beyond the reach of sheep and the forage becomes unavailable for grazing. In general there is greater seed production on sheep ranges than on cattle ranges. In spite of this, however, young reproduction is not necessarily more abundant because the ground cover is often closely utilized and the young seedlings are eaten or trampled out. by sheep 1 63

The vigor of the bitterbrush stand and especially the amount of reproduction in it is directly related to the intensity of grazing of the plants. Continuous close grazing from one year to the next is the main cause for the mass deterioration of bitterbrush stands.

Bitterbrush can withstand very heavy grazing for a long period of time because about 15 to 20 percent of the growth is protected from use by a relatively stiff woody twig stubble. The ungrazed foliage provides enough photosynthetic tissue to permit the plant to continue growth. / Plants which are known to have been closely cropped for 15 to 20 years still survive. The serious problem on heavily grazed bitterbrush ranges is the lack of young reproduction to replace the older plants as they die.

Close grazing is detrimental to flower and seed production. Measurements on 64 heavily grazed bitterbrush plants on a cattle range on the Modoc National Forest showed an average flower production of only 2 percent. A similar number of plants fenced against grazing for 6 years had an average flower production of 58 percent. It is common to see plants on which the upper ungrazed portions bear flowers and fruit in abundance while the lower grazed parts produce only occasional flowers and fruit (fig. 17).

FIG. 17. The upper ungrazed portion of this bitterbrush plant produced flowers and fruit. The lower portion which was closely grazed produced only a few flowers.

Since close grazing limits the amount of seed produced it also reduces the number of caches made by rodents. Rodent caches are virtually absent on heavily grazed areas but are found in abundance on adjoining areas protected from grazing.

The effect of close grazing on the composition of the bitterbrush stand is to eliminate the smaller plants and to reduce the number of plants per crown to a small number (table IX).

TABLE IX. Composition of a heavily-grazed bitterbrush stand, Lassen National Forest, 1940

Plants per crown	Approximate diameter of stems of plants – inches								Total	Percent
	1/16	1/8	1/4	1/2	1	1½	2	2½	3	
Number	Number of crowns									
1	4	24	18	10	4	1			61	~~78~~ 77
2		5	5	6					16	~~20~~ 21
3		1							1	1
4		1							1	1
Total	4	31	23	16	4	1			79	
Percent	5	~~40~~ 39	29	~~20~~ 21	5	1				100

Compare this table with table V on page 13 which shows the composition of a very lightly grazed stand. Notice the high proportion of the stand made up by young plants in the latter case and the large number of plants in some crowns. The ages of the plants shown in table IX are given in table X. There were no plants younger than 15 years of age in the stand.

TABLE X. Age of bitterbrush plants in a heavily grazed stand, Lassen National Forest, 1940

Age	Plants
Years	Number
0–5	0
6–10	0
11–15	0
16–20	3
21–25	6
26–30	12
31–35	23
36–40	3
41–45	1
46–50	8
51–55	10
56–60	5
61–65	2
66–70	3
71–75	2
76–80	0
81–85	1
	79

The 30- to 35-year age class contained the greatest number of plants. A high proportion of the stems ranged from 50 to 75 years old. One plant surpassed 80 years of age in spite of close past use.

Heavily-grazed bitterbrush plants respond rapidly to protection from grazing. In about two growing seasons they will usually produce enough twig growth and seed to permit seed caching by rodents.

These observations indicate that bitterbrush ranges may be regenerated and kept in good productive condition by a system of deferred and rotation grazing which will permit the plants to produce seed.

Measurements indicate the heavy winter use made of bitterbrush by deer on some areas. On the Modoc National Forest, during the winter of 1940–41, mule deer utilized about 51 percent of the twig growth produced the preceding summer. In the winter of 1941–42 the utilization of bitterbrush was about

Grazing by Deer

Bitterbrush is an important item in the diet of Rocky Mountain Mule Deer (Cervus hemionus, Rafinesque). It is also grazed by Columbian Black-tailed Deer (Cervus macrotis var. Columbiana, Richardson) on limited areas mainly in Siskiyou and Shasta Counties where the range of this species of deer overlaps the range of bitterbrush. Prong-horn Antelope (Antilocarpa Americana penninsularis) also graze bitterbrush to some extent.

Bitterbrush provides both summer and winter grazing for mule deer. It is especially important on areas like the Devil's Garden on the Modoc National Forest, the area bordering the northeastern edge of the Plumas National Forest around Doyle and similar places where mule deer concentrate by the thousands during the winter.

~~Measurements indicate the heavy winter use made of bitterbrush by deer on some areas.~~ On the Modoc National Forest, during the winter of 1940-41, mule deer utilized about 51 percent of the twig growth produced the preceding summer. In the winter of 1941-42 the utilization of bitterbrush was about 33 percent. Bitterbrush made up about 15 to 20 percent of the ground cover on this range.

The summer use of bitterbrush by mule deer is also appreciable although it is much less than the winter use. This is probably due to the fact that the deer are spread over a much larger area during the summer whereas deep snows and the migrational habits of the deer limit the areas that are grazed in winter. The summer utilization of bitterbrush by deer is quite evident (in the absence of livestock grazing) on areas where bitterbrush makes up only a small percentage of the stand. About 80 percent of the current twig growth of bitterbrush was used by deer by early August in the Burgess Spring Experimental Pasture on the Lassen National Forest in 1939. Bitterbrush made up about 1 to 2 percent of the ground cover on this range.

Bitterbrush is suffering greatly on some ranges which are grazed by livestock in summer and by deer in winter. It has not been determined yet whether the summer use by livestock or the winter use by deer is principally responsible. Portions of bitterbrush ranges on the Modoc National Forest which are too far from water to be utilized by cattle in the summer but are grazed heavily by deer in winter do not show marked signs of deterioration and lack of reproduction indicating that winter use by deer alone may not be too harmful. Bitterbrush ranges grazed by sheep and deer are generally in better condition than those grazed by cattle and deer. It seems therefore that heavy cattle grazing is most detrimental to bitterbrush. Further investigations of the relative effects of livestock and deer grazing on the growth and reproduction of bitterbrush are needed. The relative effects of the different seasons and intensities of use are important.

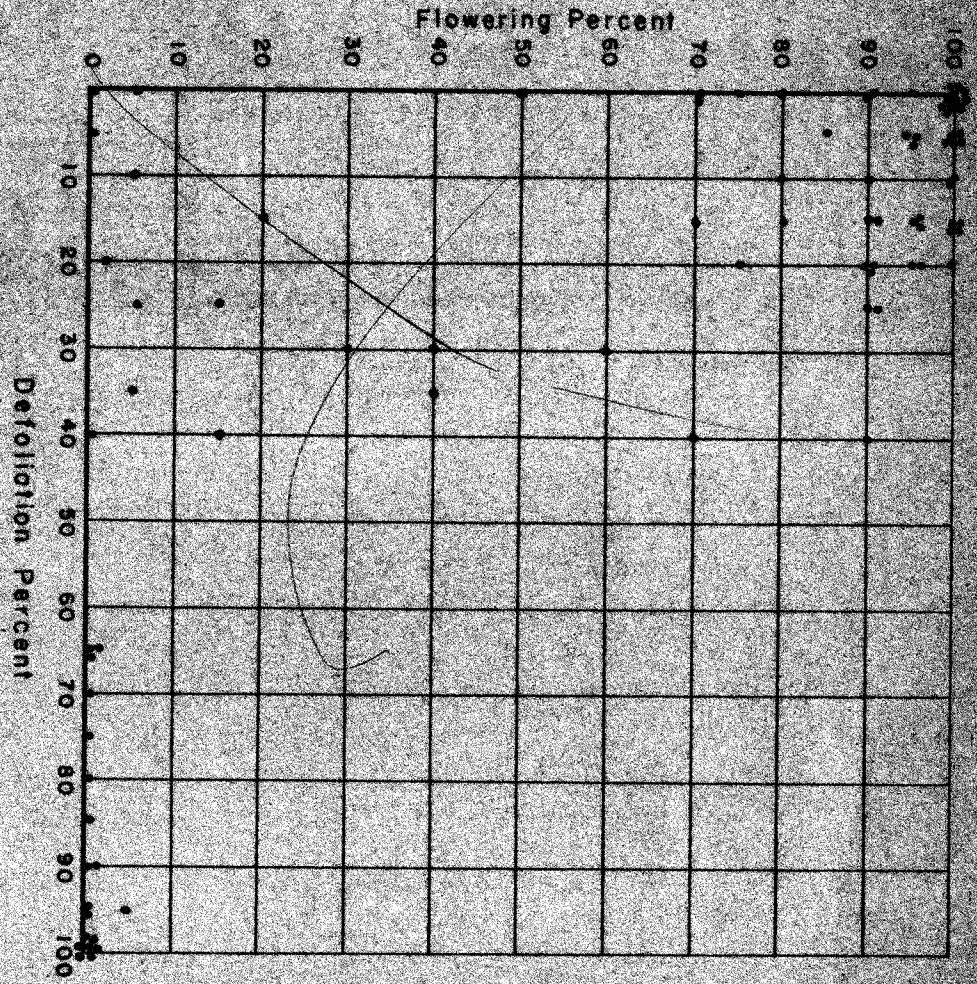
Defoliation by Caterpillars

Bitterbrush is subject to partial or complete defoliation from time to time by Great Basin Tent Caterpillars (Malacasoma fragilis) which reduces the vigor of the plants or kills them altogether. The infestations occur on localized areas from a few acres to several thousand acres in size throughout the range of bitterbrush and vary in severity from one year to the next and from one locality to another.

The degree of the injury suffered by the stand depends on the intensity and duration of the infestation and on the vigor of the plants. In light infestations only individual plants may be injured or killed. In heavy infestations virtually all of the plants in an area may be partly or totally killed. Plants weakened by grazing or other causes may be killed by a single heavy defoliation while plants in good vigor will recover quickly under the same condition.

The influence of the vigor of the plants in minimizing the damaging effect of defoliation was seen on 2 areas near Truckee, one closely grazed and the other ungrazed by livestock for many years. In late July 1941 the plants on both areas were practically completely defoliated and were brown in appearance. In the spring of 1942 plants on the ungrazed range were green and thickly covered with leaves and growing vigorously while those on the grazed area were weak and sickly. Only about 20 percent of the branches on the latter produced leaves and twig growth and all the plants had a sickly brownish appearance. The plants on the grazed area were defoliated again in the summer of 1942 and nearly all were killed.

Defoliation of 50 percent or more of the foliage of vigorous plants has the effect of reducing or preventing flower production the following season. Twig growth on defoliated plants start sooner in the spring and usually is 1/2 to 1 inch long at the time growth starts on plants which have not been defoliated the previous year.


Flowering Percent
0
10
20
30
40
50
60
70
80
90
100
Defoliation Percent
0
10
20
30
40
50
60
70
80
90
100

The Insect Laboratory of the Bureau of Entomology at Berkeley has studied the Great Basin Tent Caterpillar and its principal host bitterbrush since _____. They ~~have~~ make the following comments ~~to make~~ on the life history of this insect. "The Great Basin Tent caterpillar is known to feed on several species of shrubs including ceanothus (Ceanothus spp.), currents and gooseberries (Ribes spp.), aspen (Populus tremuloides), desert peach(Prunus andersonii) as well as its principal host bitterbrush. The insect occurs annually throughout its range, sparingly in the timbered section and more abundantly in the open brush ranges. Its damaging effects consist of defoliating the host. When severe (80 to 90 percent of leaves eaten) the host is usually killed. Severe defoliation over extensive areas occurs only during epidemic infestations.

(fig. 17A)

"The adult moths/are of a dark tawny color with narrow, brown, transverse, bands across the forewings. The females are lighter in color than the males, and are larger. They have a wing spread of about 1¼ inches. In the males the wing spread is less than 1 inch. Both sexes are strong fliers and normally migrate several miles during the flight period.

"The adult moths emerge and fly during the period from late May, thru June, and into early July. Seasonal dates depend on altitude and climatic factors. During this period the eggs are deposited in compact masses, usually in a band around the smaller stems of the host. ~~Incubation is prolonged~~. The young caterpillars develop within the egg shells before the fall of the year, but the eggs do not hatch until the following spring.

"The young caterpillars leave the egg shells in March and early April and immediately set upon the leaves of the host. Feeding is heavy and the caterpillars grow rapidly, reaching their full size by the middle of May. The caterpillars are gregarious; the ~~product of~~ from one or several egg masses congregate in a single colony and remain together until pupation takes place.

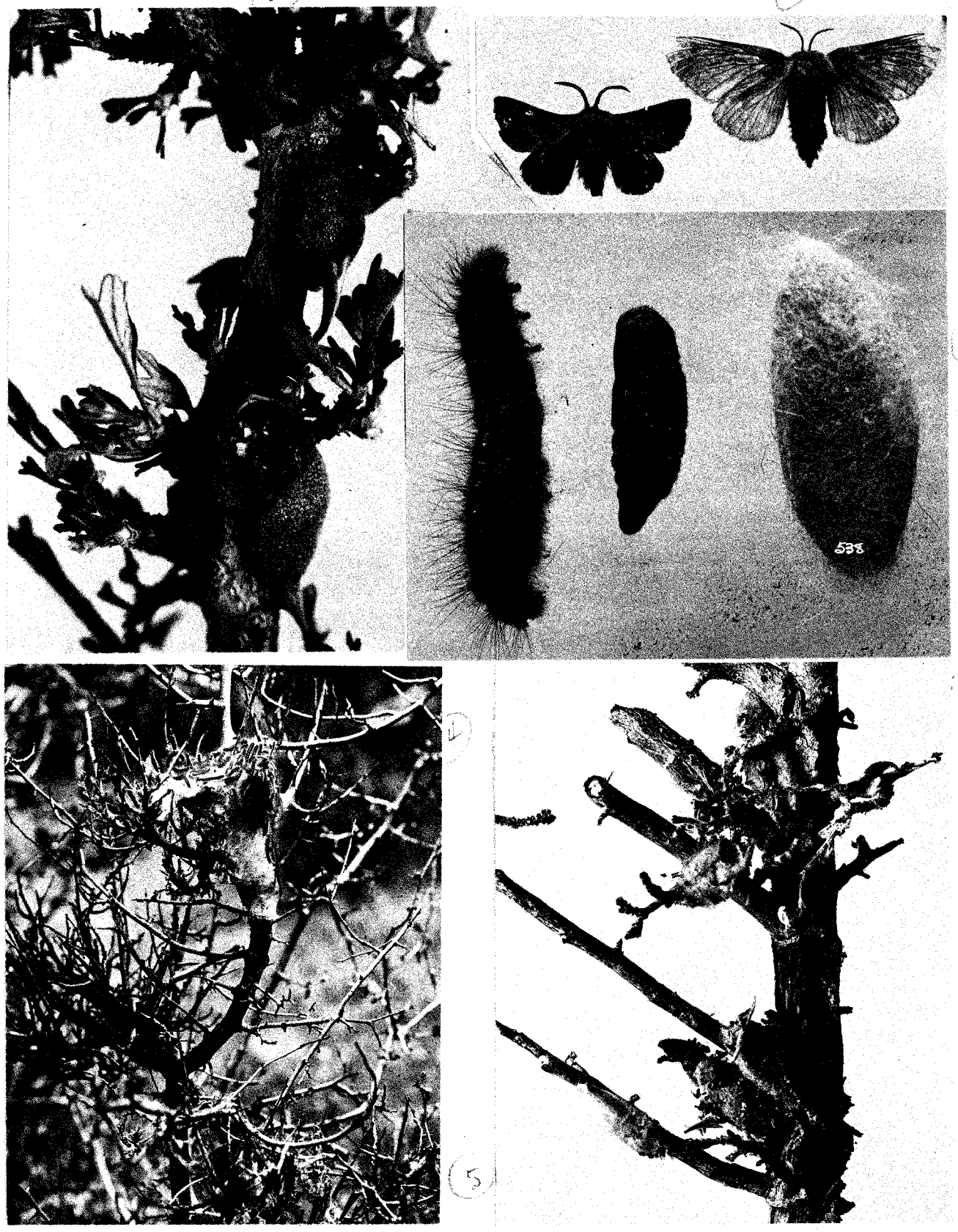


FIG. 17A. Life history of the Great Basin tent caterpillar, Malacosoma fragilis, Strech. 1: Adult moths, male and female. 2: Egg masses on bitterbrush. 3: Full grown caterpillar, pupa, and cocoon. 4: Colony of caterpillars on web, or, "tent," attached to bitterbrush. 5: Cocoons attached to stem of host.

During this stage they spin large, web-like nests of silken strands in the foliage of the host in which they remain and feed. The common name "Tent Caterpillar" is derived from these nests or tents. It is during this stage only that damage to the host occurs.

"Pupation occurs inside hairy cocoons which are spun by the caterpillars and are composed of body hairs from the caterpillars and spun silk. They are usually attached to stems below the tents in which the caterpillars feed. Pupation begins in late May and extends thru June. About 2 weeks is spent in the chrysalid stage when the new adults emerge, thus completing the life cycle. There is only one generation of moths each year, but there is some overlapping of broods.

"Control of epidemics is usually brought about thru natural causes within 2 or 3 years from the beginning of epidemics and occurs as a result of a proportionate increase of insect enemies which prey upon the eggs and caterpillars. It has been demonstrated that artificial control can be secured by the use of insecticides. Only those that are non-poisonous to grazing livestock and the host can be employed. Light penetrating oils meet these requirements and are highly toxic to the insect in both the egg and larval stages. "

These observations on livestock grazing and defoliation by caterpillars indicate that heavy removal of the foliage of bitterbrush retards or completely prevents seed production and therefore the establishment of reproduction. The leaving of 50 percent or more of the previous year's twig growth on the bush to maintain the vigor of the plant and to allow seed to be produced seems necessary for the reproduction of bitterbrush which depends on seed formed on previous year's twigs.

Where bitterbrush makes up most of the forage on the range, a reduction in numbers of livestock may allow sufficient number of branches to go ungrazed to supply adequate seed for reproduction. The growth habit of bitterbrush indicates that it would be desirable to protect the same plant from grazing two years in succession to allow for adequate seed production. The first year ~~would~~ is needed to produce the necessary twig growth on which the seed is borne ~~Part~~ and of the second year ~~would be required~~ to allow the seed to grow and mature. This suggests that a system of deferred and rotation grazing involving nonuse of the same portion of the range for two full seasons in succession approximately every ~~3~~ or 4 or 5 years would encourage satisfactory growth and reproduction of bitterbrush. Deferred and rotation grazing ~~is~~ would be beneficial not only to bitterbrush but to the range as a whole.

Combined with other proper management practices the switching of the class of stock from cattle to sheep may promote the establishment of bitterbrush reproduction on ranges where it is lacking from too close use by cattle. More information is needed on the amount of current growth that should be left on the plant to permit sustained growth and reproduction. Changes in the nutritive qualities of bitterbrush, and its ability to withstand grazing at different times of the season are also needed to determine its most desirable and profitable period of use. ~~(See 24_1 - 24_2)~~

EFFECT OF BURNING

In California bitterbrush is killed outright in most cases by fire. (fig. 18) Thousands of acres have been destroyed in the past. Even a relatively light scorching of the crowns and stems is fatal ~~(Fig. 18)~~. The thin bark and the limited cambium tissue in many stems permits the plant to be ~~many~~ easily killed. Under California conditions bitterbrush does not

FIG. 18. Bitterbrush is almost always killed by fire in California.

resprout following burning except in rare instances. Only one case of sprouting following burning has been seen by the author in California. This was near Delleker on the Plumas National Forest. An intense burn swept over this area on July 24, 1941 probably at a time when the seed was ripening. When examined on July 29, 1942, twenty-two percent of the plants were found to be resprouting. Some of the sprouts had already died but many looked like they would grow into vigorous bushes if they were not grazed too heavily. Twelve other burned areas examined showed no evidences of sprouting. No cases of sprouting have been previously reported from the national forests in California. (Believe one case on Sequoia Forest, but Ichina species is glandulosa) CAS

The natural reestablishment of bitterbrush in the interior of large burns is a longtime process because the seed has to be supplied by plants located around the edges of the burn. Seed from this source is carried into burns in appreciable quantities by rodents. It is the principal means by which bitterbrush becomes reestablished naturally on burned areas.

On an area near Burney Mountain on the Lassen National Forest, rodents cached bitterbrush seed several hundred yards inside the margins of a burn which occurred in 1936. Some of the seedlings from these caches were 12 inches in diameter and 12 inches high in 1942. Many were 6 years old and others were 4 years old indicating that plantings were made in 1937 and 1939. Planting of bitterbrush on burns by rodents has been observed in all cases where there was an available seed supply around the margins of the burn. Rodents can play an important supplementary role in artificial reseeding of bitterbrush.

Only occasional seedlings germinate on bitterbrush ranges following burning. Apparently fire kills the seed. Certainly it does not stimulate their germination. There does not seem to be any delayed germination of bitterbrush on either burned or unburned areas which suggests either that rodents gather

and eat the seed which does not germinate from previous years' seed crops, or that bitterbrush seed does not remain viable in the ground after one year.

Dense stands of downy chess (Bromus tectorum) which usually invade burned-over bitterbrush ranges retards the extensive caching of bitterbrush seed. The lack of bitterbrush reproduction in many areas where seed is apparently produced in abundance seems to be due to the dense stand of downy chess in the understory. The denser grass stands not only prevent the widespread activity of certain rodents (chipmunks in particular) but probably stifle many bitterbrush seedlings by shading and competing with them for moisture. Bitterbrush does become reestablished slowly on areas which support a light or only a moderate cover of downy chess.

Fire therefore not only destroys the bitterbrush plants and seed but creates conditions which may make it difficult for the stand to become reestablished in a reasonably short period of time.

ARTIFICIAL RESEEDING

The techniques used by rodents in planting and getting successful establishment of bitterbrush suggests the use of the following procedures in artificial revegetation of this species.

1. Plant mature viable seed.
2. Plant several seeds, perhaps 5 to 10 in one spot.
3. Bury the seed ½ to 1½ inches deep in mineral soil.
4. Where bushes are present plant the seed in the interspaces.
5. Plant in the summer or fall of the year.
6. Plant in strips or belts and leave it to rodents to reseed the intervening areas. No doubt further study will bring about improvement or modification of these initial suggestions. Successful reseeding of bitterbrush will probably depend on some control of rodents at least during the year of planting to prevent the seed from being eaten, and on the control

of livestock grazing after germination of the seedlings to permit their establishment and growth.

Selection of Seed

The viability of the seed depends on seasonal growing conditions, the stage of growth at which the seed is picked, the vigor of the plant from which the seed is collected, the genetic make-up of the seed, and the care taken in its handling and storage. Before reseeding yields consistently successful results, seed will have to be obtained from areas or plants which are known to produce viable seed. The good seed produced in certain years should be collected in quantity and stored for future planting. Bitterbrush seed which was stored in air-tight containers for nearly 3 years at 40° F. have germinated. Under proper conditions bitterbrush seed can probably be stored for a much greater period of time. There is room for considerable genetical and physiological work on the selection, storage and germination of bitterbrush seed.

Bitterbrush seed ripens very rapidly in the latter part of July or early August and most of the heavier plump ones fall to the ground within 4 or 5 days after the first seeds start dropping. The seeds that ripen first are located on the lower branches while those ripening last are near the ends of the uppermost branches. Care should be exercised to collect seed from the part of the plant that is producing ripe seed. The red juice of the endosperm should be fairly well solidified. Seed may be collected by stripping the branches by hand with gloves.

Depth of Planting and Ground Preparation

The advantages of getting seed planted 1/2 to 1½ inches deep in mineral soil were shown on some experimental plots on the Modoc National Forest. Nine hundred and twelve bitterbrush seedlings were found to germinate on 12 plots totaling 0.48 of an acre on which the soil was heavily

scarified with a tractor and road ripper. Only 132 or about 1/7 as many seedlings germinated on comparable untreated areas. At the end of 2 years, there were still 255 seedlings on the treated areas and 45 on the untreated. Scarification buried many seeds in mineral soil and favored their germination and establishment.

Time of Planting

Natural planting of bitterbrush seed in the field occurs in the summer and fall. During the winter, these seeds are subjected to the effects of stratification which tends to promote early and uniform germination in the spring. Fall planting of untreated seed is therefore indicated.

Germination tests (table XI) by the Division of Forest Influences of The California Forest and Range Experiment Station have shown that fully-ripened bitterbrush seed stratified for 3 months at 40° F. and then planted in soil at about 70° F. gave consistently high germination. The first seeds germinated within a few hours and none later than 5 days after being planted in the soil and subjected to the higher temperature. The elapsed time between the germination of the first and last seedlings ranged from 14 to 19 days. Unstratified seed subjected to the same germinating conditions gave a lower percentage germination and the period of time over which the seedlings germinated ranged from 40 to 79 days. Further study might show that spring planting with partly pre-germinated stratified seed can be successfully carried out.

Method of Planting

The planting of bitterbrush seeds in spots can readily be relatively easily carried out by hand. A mattock may be used to dig the small shallow holes for the seeds or planting may be done with a corn planter adapted to handle bitterbrush seed. Sowings may be also made in shallow furrows made by hand or with power equipment such as a tractor-drawn cultivator or

TABLE XI. Germination tests of bitterbrush seed

Seed lot no.	Place of seed collection	Pre-germination treatment	Number of seeds tested	Time between end of pre-germination treatment and germination of first seedling	Total period of germination	Total percent germination
2695	Modoc N. F.	Stratified 3 mos. at 40° F.	100	0	19 days	69
6626	"	Stratified 3 mos. at 40° F.	25	5	13 days	64
1462	Eldorado "	Stratified 3 mos. at 40° F.	25	2	4 days	24
3299	"	Stratified 3 mos. at 40° F.	100	0	2 days	4
2695	Modoc N. F.	Cold storage 33 mos. Stratified 2½ mos. at 40° F.	100	0	5 days	59
2695	"	Cold storage 33 mos at 40° F.	100	11	45 days	15
6626	"	Planted in soil at 40° F. for 3 mos.	20	5	40 days	35
2695	"	None	100	-	79 days	6
1462	Eldorado "	None	50	-	-	0

Note: Germination was carried out in soil in the greenhouse at about 70° F.

road ripper where ground conditions will permit. However most bitterbrush ranges are strewn with rocks, down logs and other ground obstructions which make the cost of operating machinery too high to be economical. Furthermore spot planting can probably only be made by hand. Hand planting may be adapted to any ground conditions.

Intensity and Coverage of Planting

It seems unnecessary to go to the expense of covering an area completely with any given spacing or intensity of planting. The planting of strips or belts would be all that would be required on large areas. Rodents can be expected to plant up the interspaces between strips with the seeds produced by the plants sown on the strips. Observations have shown that even in the sparsest bitterbrush stands, rodents do not eat all of the seed produced in good seed years but plant some of them in caches. There is some assurance therefore that the planted strips would provide seed for interplanting by rodents.

~~xBitterbrush produces xx 18,000 to 24,000 good seed xxxxxxxxxxxxxxx~~

There are from 18,000 to 24,000 good bitterbrush seeds in a pound depending on the size of the seed. A pound of seed would be sufficient to plant an acre with seed spots(containing 5 to 10 seeds each) spaced at 4-foot intervals along lines located 4 feet apart. This intensity of planting is the same as the average distribution of the bushes in many bitterbrush stands.

A 20-foot wide belt planted at this intensity should provide sufficient plants for further reseeding Rodents are known to travel and plant bitterbrush seed as much as 200 yards from the nearest seed source but the greatest number of plantings are probably made at a closer distance. A spacing of about 400 feet between belts does not seem too great but what the rodents could plant up the interspaces.

These suggestions on the artificial reseeding of bitterbrush are based almost entirely on the ecological behavior of bitterbrush. Unfortunately the only experimental planting made to date was with shrivelled seed. The seed was planted 1 to 2 inches deep in mineral soil in rows in the fall of the same year that it was collected. One to 2 percent germinated the following spring. Rodents did not seem to dig up any of the seed, perhaps because of its poor quality. The two most critical points in getting bitterbrush established artificially center around getting viable seed and protecting it from rodents until it has germinated. Further seeding trials may show these points not to be so important.

SUMMARY

1. Bitterbrush is one of the most important and widely distributed browse plants on western ranges. It is utilized by livestock and the various forms of wildlife.

2. Many bitterbrush ranges in California are being deteriorated and are lacking in reproduction. Therefore studies and observations were started in northeastern California in 1940 to provide a better basis for managing this browse.

3. In California, bitterbrush reproduces essentially from seed. A given year's seed crop is borne on twigs grown in previous years.

4. Bitterbrush stands become established mainly from the seeds planted in caches by rodents. Chipmunks, golden mantel ground squirrels, and mice probably do most of the caching.

5. Continuous close grazing of bitterbrush by livestock is the principal cause of the lack of reproduction on many bitterbrush ranges. Cattle grazing is generally more destructive than sheep grazing.

6. Winter grazing of bitterbrush by mule deer is very heavy in portions of northeastern California. The relative influence of this intensity and

season-of-grazing on the vigor of the plant compared to use by livestock has not yet been determined.

7. Defoliation of bitterbrush by caterpillars frequently leads to the destruction of the stand especially if heavy infestations continue the second year. Heavily grazed plants are killed more readily by caterpillar defoliation than lightly or ungrazed plants. If about 50 percent or more of the bitterbrush plant is defoliated, flowering usually does not occur the following year.

8. Bitterbrush is nearly always killed by fire in California. Fire apparently destroys most of the seed in the soil since it has not been observed to germinate following burning of the stand. Natural reestablishment of bitterbrush on burns is a relatively slow process and is brought primarily about by the planting of seeds by rodents.

9. With proper management of livestock grazing and control of rodents, artificial reseeding of bitterbrush can probably be carried out if the planting techniques used by rodents are followed closely. Better and improved methods can be expected from further study.

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