Mike Connor

UNIVERSITY OF CALIFORNIA SIERRA FOOTHILL RANGE FIELD STATION BEEF & RANGE FIELD DAY

Photo by C.A. Raguse

Aerial view of the Sierra Foothill Range Field Station with Englebright Reservoir in the foreground.

APRIL 21, 1987
BROWNS VALLEY, CALIFORNIA

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EFFECT OF WEATHER ON RANGE FORAGE PRODUCTION

Melvin R. George

INTRODUCTION

When will this year's range forage germinate? How long will the winter growth period last? Will late rains prolong the green season? When should range be reseeded? These are questions annually asked by California ranchers and range managers.

The timing and length of the fall (germination and seedling establishment), winter (slow growth), and spring (rapid growth) seasons can vary substantially from normal depending on the timing of germinating rains, onset of cold temperatures, onset of warm temperatures, and end of effective spring rains. Fall is the period between germination and the onset of cold temperatures. Winter is the time from the onset of cold temperatures until warming spring temperatures begin. Spring is the period of warm temperatures until soil moisture is depleted. Summer begins when soil moisture is depleted and ends with fall germinating rains. If a prolonged dry period follows fall germinating rains, a second germination may occur with later rains. If germinating rains occur after it turns cold, there is no fall season for that year.

METHODS

For 23 years of weather data from SFRFS the four events (germinating rains, cooling winter temperatures, warming spring temperatures, and soil moisture depletion) were estimated from analysis of daily minimum and maximum temperature and precipitation according to the following criteria. Based on past research at SJER germination begins seven days after the first rainy day in a week where 1 inch of rainfall occurred (Figure 1).

Degree day accumulations were used to determine cold and warm periods. Degree day accumulations are a means of measuring physiological time when plant growth can occurr. For a broad selection of cool season forages growth begins at about 41 F. A mean daily temperature of 42 F would be 1 degree day above the critical temperature. Several methods for calculating degree days were discussed in California Agriculture (Jan-Feb, 1983). The methods used by the California Integrated Pest Management computer group were used in this analysis.

The winter season begins on the first cold day in the first cold period of 7 days that averaged less than 5 degree days per day. The spring season began on the first warm day in the first warm period of 14 days that averaged greater than 5 degree days per day. The criteria for the beginning of winter and beginning of spring (end of winter) were established by averaging the daily accumulated degree days for the periods between the winter and spring inflection points on the seasonal accumulated degree day curve. A sustained period where an average of five degree days or less are accumulated each day was determined to be a good indicator of winter conditions.

Peak forage crop ends with the onset of the dry season which, on the average, begins 15 days after the last rainy day in a week where 1 inch of rain occurred but was not allowed to exceed April 15. Due to plant maturity, rainfall after April 15 is seldom effective.

The starting dates for each season were analysed to determine the weekly probability of fall, winter, spring, and summer starting. Each season and year was classified as cold, average or warm and dry, average or wet. Average conditions were those that fell within 0.68 standard deviations of the mean for all years. Those below that range were cold (degree days) or dry (rainfall). Those seasons that fell above the average range were classified as warm or wet.

RESULTS AND DISCUSSION

Table 1. summarizes the beginning dates, accumulated degree days, and rainfall for fall, winter, spring, and summer for SFRFS. Figures 1-4 contain the accumulated probabilities at weekly intervals of each season starting.

There is a high probability of fall beginning between October 5 and October 12 at SFRFS. There appears to be a rather poor chance of receiving a germinating rain the week of November 2 - November 9 while the previous and following weeks have higher probabilities of a germinating rain. The onset of winter is clustered around early November to early December (Figure 2).

The onset of warming conditions is widely spread from late January to early May (Figure 3). However, the starting dates are clustered in the mid February to early April period. SFRFS has an extremely high probability of starting spring between February 10 and February 17.

The dry season begins as early as the second week in March and the probabilities rise to a peak the week of April 25 to May 2. The analysis method forced the dry season to begin no later than late April discounting the value of precipitation after mid April.

The probabilities for each season of receiving a wet, average or dry and a warm, average or cold season are presented in Table 2. When a season is cold or dry, plant growth can be expected to be below average. When warm conditions coincide with average or above average moisture conditions plant growth can be expected to be average or above average.

CONCLUSION

Weather analysis is a useful tool for determining expected timing of weather and plant growth events and it can be used to assess risk. Knowing when to expect the first germinating rain in fall can help to determine average dates for range seeding as well as the expected date of fall green up. Knowing the length of winter and recognizing deviations from normal may influence short term stocking and supplementation decisions. The expected date of soil moisture depletion would influence the decision to market or move livestock.

Economic evaluation of range improvement practices frequently requires productivity projections over several years. Weather variability can be factored into those projections by using the probabilities for average and above or below average temperature and moisture conditions as a measure of weather risk.

Table 1. Average beginning date, Accumulated degree days, and rainfall for each season (day 1 = September 1).

		Fall	Winter	Spring	Summer
Starting Date		58	88	181	225
	sd	24	19	31	15
ADD		488	383	569	1351
	sd	327	219	368	463
Rainfall (in)		5.26	14.47	5.79	24.58
	sd	4.58	9.26	5.43	9.96

Table 2. Historical probabilities of dry, average and wet, and cold, average and dry condtions for each season at SFRFS.

	Fall	Winter	Spring
Dry	30	26	30
Average	35	52	43
Wet	22	22	22
No Season	13	0	4
Cold	30	22	26
Average	35	57	48
Warm	22	22	22
No Season	13	0	4

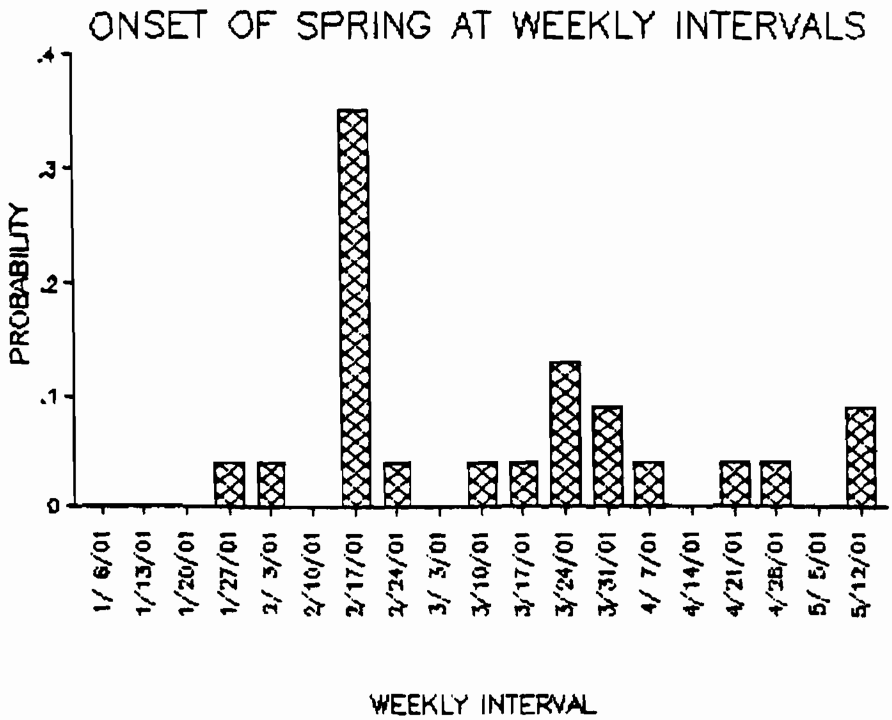
FIGURES

Figure 1. Germination at Weekly Intervals

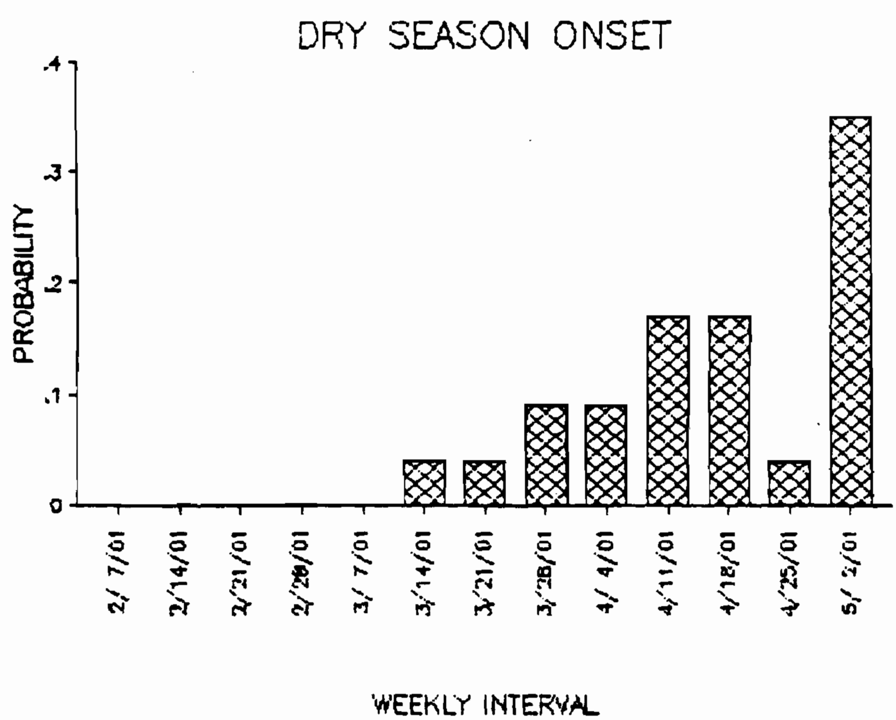
Figure 2. Onset of Winter at Weekly Intervals

Figure 3. Onset of Spring at Weekly Intervals

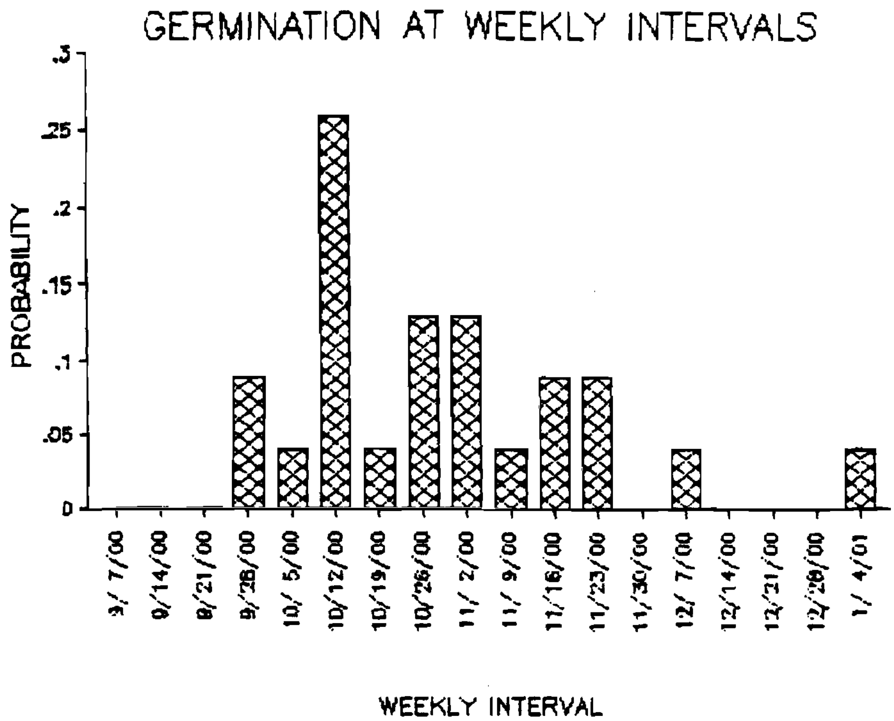
Figure 4. Dry Season Onset

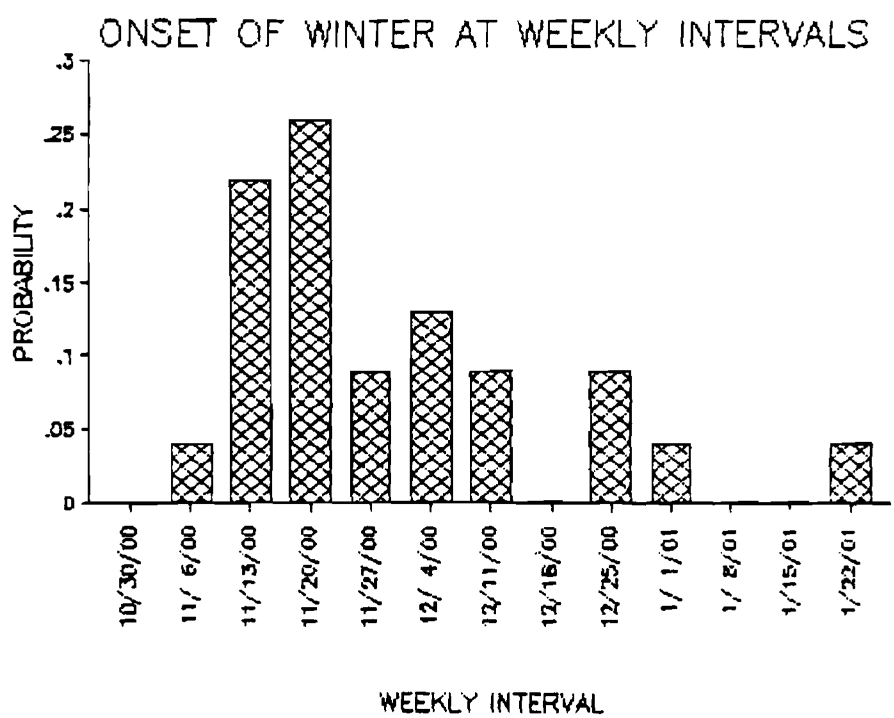


ONSET OF SPRING AT WEEKLY INTERVALS
PROBABILITY
.4
.3
.2
.1
0
1/ 6/01
1/13/01
1/20/01
1/27/01
2/ 3/01
2/10/01
2/17/01
2/24/01
3/ 3/01
3/10/01
3/17/01
3/24/01
3/31/01
4/ 7/01
4/14/01
4/21/01
4/28/01
5/ 5/01
5/12/01
WEEKLY INTERVAL



DRY SEASON ONSET
PROBABILITY
.4
.3
.2
.1
0
2/ 7/01
2/14/01
2/21/01
2/28/01
3/ 7/01
3/14/01
3/21/01
3/28/01
4/ 4/01
4/11/01
4/18/01
4/25/01
5/ 2/01
WEEKLY INTERVAL


GERMINATION AT WEEKLY INTERVALS
PROBABILITY
0
.05
.1
.15
.2
.25
.3
9/ 7/00
9/14/00
9/21/00
9/28/00
10/ 5/00
10/12/00
10/19/00
10/26/00
11/ 2/00
11/ 9/00
11/16/00
11/23/00
11/30/00
12/ 7/00
12/14/00
12/21/00
12/28/00
1/ 4/01
WEEKLY INTERVAL


ONSET OF WINTER AT WEEKLY INTERVALS
PROBABILITY
0
.05
.1
.15
.2
.25
.3
10/30/00
11/ 6/00
11/13/00
11/20/00
11/27/00
12/ 4/00
12/11/00
12/18/00
12/25/00
1/ 1/01
1/ 8/01
1/15/01
1/22/01
WEEKLY INTERVAL

RANGE COW NUTRITION

J. R. Dunbar, C. B. Wilson, and J. M. Connor

University of California, Davis

In California it is estimated that the cost of maintaining the range beef cow accounts for approximately $400.00 annually. One of the major ways to increase profitability of the range cow herd is to reduce this cost.

Sixty percent of this $400 represents feeding the cow. It is obvious that any reduction in this expense may have a large effect on profitability of the enterprise. However, any reduction in feed inputs may result in a penalty in terms of cow and calf performance. Before decisions can be made regarding sound feeding management it is necessary first to understand the relationships between nutrition and performance and how these can be modified by cow body condition (Herd and Sprott, 1986).

Body Condition Scoring

Body condition scoring was developed from an Australian method and can be used by anyone working with cattle to assess the fatness or condition of cows, calves, or bulls. It can serve as a valuable management aid in cattle production. A description of body condition scores is given in Table 1.

Condition is assessed by feeling with finger pressure along the top, and side of the backbone, in the loin area immediately behind the last rib and above the kidneys. Figure 1 illustrates the important handling points which are assessed in the following order:

1. The sharpness or roundness of the spinous processes of the lumbar vertebrae (the bony points rising upwards from the back).

2. The prominence and degrees of cover of the transverse processes of the vertebrae (the bone protruding from each side of the backbone).

3. The extent of muscular and fatty tissues underneath the transverse processes (judged by the ease with which the fingers pass under the ends of the bones).

4. The fullness and fat cover of the eye muscle (judged by pressing between the spinous and transverse processes).

TABLE 1. DESCRIPTION OF BODY CONDITION SCORES.

1.	**Very Thin**	Bone structure of shoulder, ribs, back, hooks and pins sharp to touch and easily visible. Little evidence of fat deposits or muscling.
2.	**Thin**	Beginning of fat cover over the loin, back, and foreribs. Backbone still highly visible. Processes of the spine can be identified individually by touch and may still be visible. Spaces between the processes are less pronounced.
3.	**Normal**	12th and 13th ribs not visible to the eye unless animal has been shrunk. The transverse spinous processes can only be felt with firm pressure to feel rounded - not noticeable to the eye. Spaces between the processes are not visible and only distinguishable with firm pressure. Areas on each side of the tail head are fairly well filled but not mounded.
4.	**Fat**	Ends of the spinous processes can only be felt with very firm pressure. Spaces between processes can barely be distinguished at all. Abundant fat cover on either side of tail head with some patchiness evident.
5.	**Very Fat**	Bone structure not seen or easily felt. Tail head buried in fat. Animal's mobility may actually be impaired by excess amount of fat.

It is recommended that cattle be assessed to the nearest half score. So the range becomes 1, 1-1/2, 2, 2-1/2, 3, 3-1/2, 4, 4-1/2 and 5.

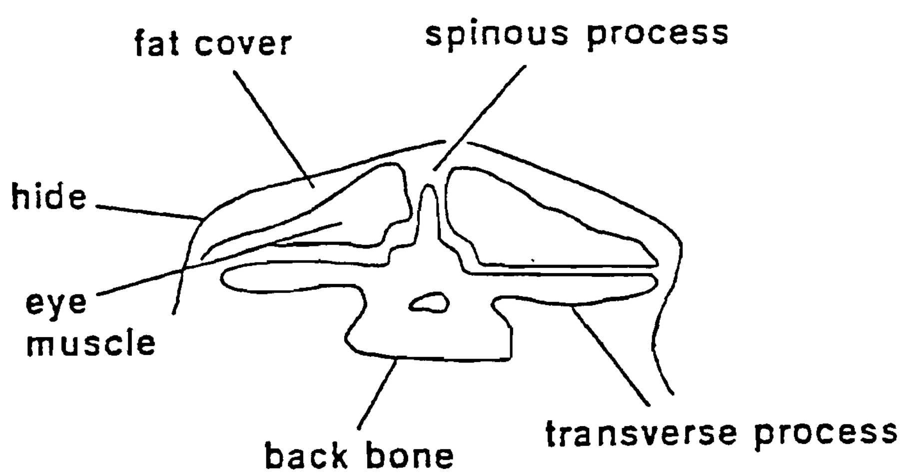


FIGURE 1. CROSS SECTION THROUGH LUMBER REGION.

Figure 2 illustrates the changes in body weight throughout the year relative to cow weight at calving and also the target body scores at different stages of the production cycle. It is essential that cow nutrition be considered on a year-round basis, and that no individual stage of production be dealt in isolation.

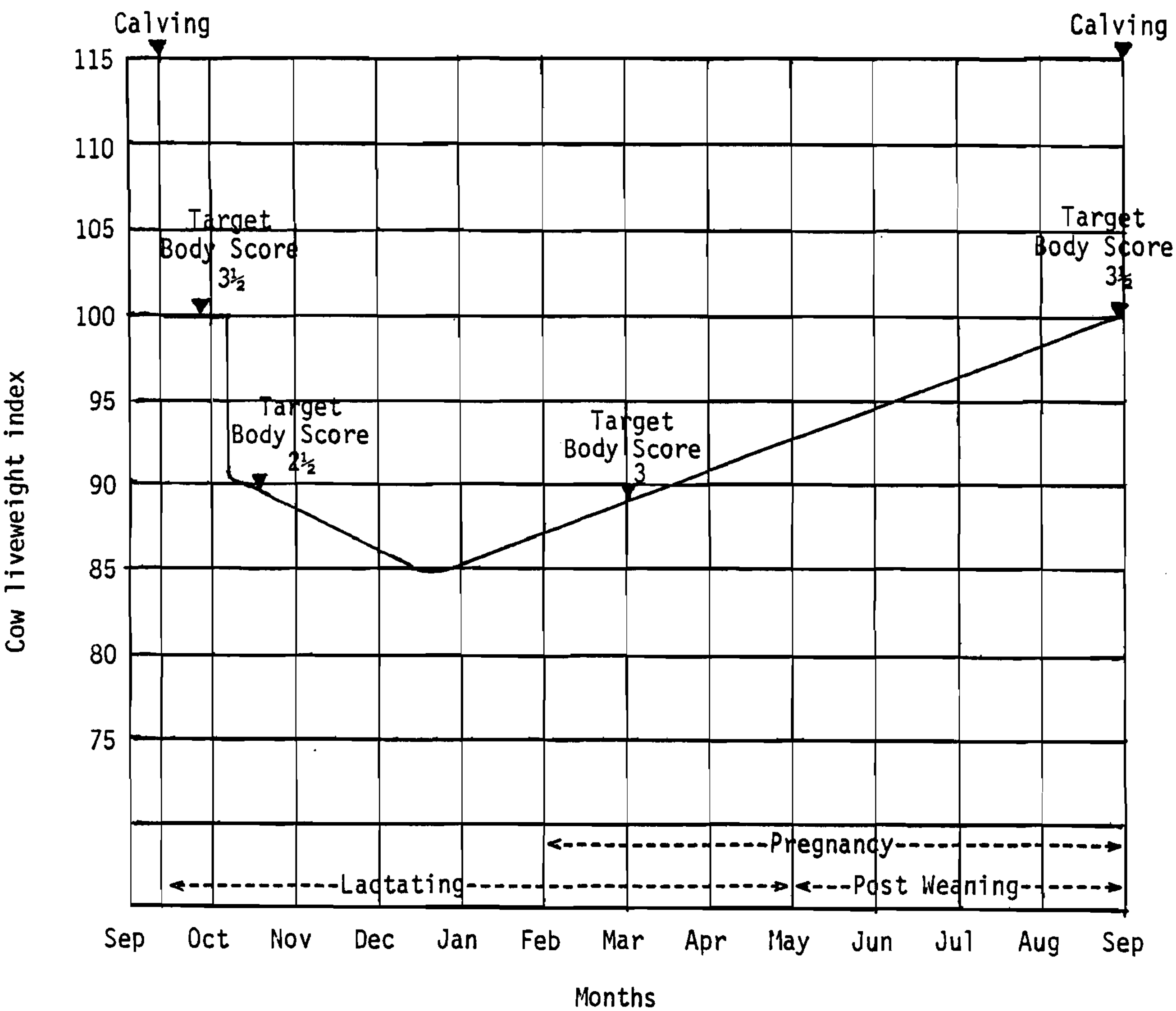


FIGURE 2. COW LIVEWEIGHT AND TARGET BODY SCORES (MATURE COW CALVING WEIGHT = 100).

The relationship between cow body condition score at mating and on pregnancy rate is shown in Table 2.

TABLE 2. EFFECT OF BODY CONDITION DURING THE BREEDING SEASON ON PREGNANCY.

	Body Condition During Breeding		
	2+ or less	3	3+ or more
Number of cows	122	300	619
Percent pregnant after 150 days	58	85	95

Supplemental Feeding

The beef cow has the ability to store vital nutrients when feed conditions are best and draw upon these reserves to meet requirements when forage is of poor quality or short in supply. To achieve the desired body condition during calving and breeding seasons, supplementation of the cow herd may be required.

Supplemental nutrients are typically provided to the fall calving range cow herd in the latter portion of the dry season (August to October) and the inadequate green forage season (October to January).

The overall reasons for feeding supplements are to (1) increase profits, (2) correct nutrient deficiencies in the forage, and (3) support acceptable condition and production.

Wagnon and co-workers (1959) at the San Joaquin Experimental Range showed that feeding an average of 380 pounds of cottonseed meal per cow per year resulted in 115 extra pounds of weaned calf per breeding. However, a five-year study by Morris (1985) at the Sierra Foothill Range Field Station indicated that when the range is moderately stocked, supplementary feeding is unlikely to be profitable.

In spite of this conflict, most cattlemen feed the cows that need it when they need it. They recognize the importance of feeding supplements and adjusting for changes in the weather and the condition of the range and cattle.

Supplement Form

The availability of numerous types and forms of feed for supplementing the range cow herd, prompts many questions by cattle managers. Low profit margins, rising costs of supplemental feed and labor, as well as vehicle expenses involved in distribution, makes the decision of supplemental form an important management consideration.

The objective of a cooperative study with CSUF was to evaluate four common supplemental feeds (alfalfa hay, cottonseed meal-salt mix (CSM), commercial block and commercial liquid supplement) on cow and calf performance and to compare the cost of handling, storing, and distributing the four supplements. The trial was conducted for three years to eliminate the effect of forage availability in any one year and to evaluate supplement effect over a prolonged period. The net cost of feeding each supplement was also determined.

In the final analysis, the performance of the mature cows and their offspring was not affected by the form in which the supplements were fed. There was, however, a negative effect on the re-breeding performance of three-year-old cows. Combined across all supplement treatments, 3 three-year-old cows failed to re-breed as efficiently as cows 4 years and older. Economic analysis of the data showed the income per cow over supplement cost was the greatest for the liquid and CSM followed by the block and hay (Table 3).

TABLE 3. INCOME PER COW OVER SUPPLEMENT COST.

Supplement Form	Mean Weaning Wt per Cow	Price per Cwt	Income per Cow	Supplement Cost Per Cow $	Income over Supplement Cost $
Hay	493	@.65/cwt	$320.45	64.22	256.13
CSM	494	@.65/cwt	$321.10	37.82	283.28
Liquid	511	@.65/cwt	$323.15	37.40	294.75
Block	509	@.65/cwt	$330.85	69.09	261.84

Bypass Protein Suspensions in Liquid Supplements

Liquid supplements have been used for years to provide protein, energy, mineral, vitamins, and additives to cattle in grazing situations. These supplements are normally high in non-protein nitrogen which serves as a substrate for microbial protein synthesis.

Research, however, has shown that the utilization of urea by range cattle fed low quality roughage diets is relatively poor compared to natural protein. In the past few years, xanthan gums and clay have been used to suspend small particles in liquid supplements. Supplementing calves or cows in late gestation or early lactation with protein that bypasses rumen degradation may complement microbial synthesis and improve performance. Feeding a bypass protein; however, does not ensure increased animal performance (NRC, 1984).

Table 4 presents the value of protein in several sources as a percentage of soybean meal (Klopfenstein and Goedeken, 1985).

TABLE 4. RELATIVE PROTEIN VALUES OF PROTEIN SOURCES.

Protein Sources	Protein Values (percentage)
Soybean meal	100
Dehy, 17% protein	125
Dehy, 20% protein	150
Brewers grains	190
Distillers grains	200
Distillers grains plus solubles	150
Corn gluten meal	200
Blood meal, ring dried	250
Blood mean, old process	200
Meat meal	180
Cottonseed meal 41% protein	160

In two studies by Goedeken, et. al., (1986), growth trials were conducted in drylot to determine the effects of suspending meat meal and blood meal in liquid supplements fed in a complete diet or in lick tanks on growing calf performance.

Data Tables 5 and 6 indicate that some bypass protein liquid supplements are more palatible than urea supplements. Gains and feed efficiency can be increased when some bypass protein is included in liquid supplements compared to urea liquid supplements.

TABLE 5. SUSPENDED LIQUIDS IN MIXED RATIONS VERSUS LICK TANKS.

Item	Soybean Meal	Urea		Blood Meal		Blood meal-Meal Meal	
		Mixed	Lick Tank	Mixed	Lick Tank	Mixed	Lick Tank
Daily intake, lb:							
Total	17.16	16.02	15.18	15.45	15.62	15.62	15.62
Supplement	2.51	2.3	1.96	2.27	2.97	2.24	2.57
Daily gain, lb	2.29	1.80	1.78	2.11	2.31	2.05	2.13
Feed/Gain	7.14	8.33	9.09	7.69	6.67	7.69	7.14
Coefficient of variation	14	12	16	15	18	16	
Protein efficiency	.47	—	—	.69	.92	.55	.72

TABLE 6. MEAT MEAL AND BLOOD MEAL IN SUSPENDED LIQUIDS.

Item	Soybean Meal	Urea	Blood Meal Mixed	Blood Meal Lick Tank	Meat Meal Mixed	Meat Meal Lick Tank
Daily intake, lb:						
Total	15.53	15.33	15.75	15.41	16.21	14.65
Supplement (101 d)	2.53	2.50	2.49	2.25	2.65	2.15
Supplement (44 d)	2.01	1.93	2.35	1.43	2.49	1.51
Daily gain, lb (101 d)	2.02	1.55	1.75	1.57	1.57	1.41
Daily gain, lb (44 d)	1.99	1.60	2.04	1.59	1.75	1.46
Feed/Gain, lb	7.69	9.83	8.94	9.50	10.21	10.33
Coefficient of variation	13.04	22.89	20.07	27.66	17.42	21.05
Protein efficiency	.439	—	.497	.023	.043	-.313

Two steer grazing trials were conducted by Anderson, et. al., (1987) to evaluate bypass protein on brome grass pasture. Three levels of bypass protein were provided (.25, .50, and control. Trial 1 utilized 59 crossbred steers (610 lb) and in Trial 2,60 crossbred steers (538 lb) were used. Figure 3 illustrates the growth response above that of the controls.

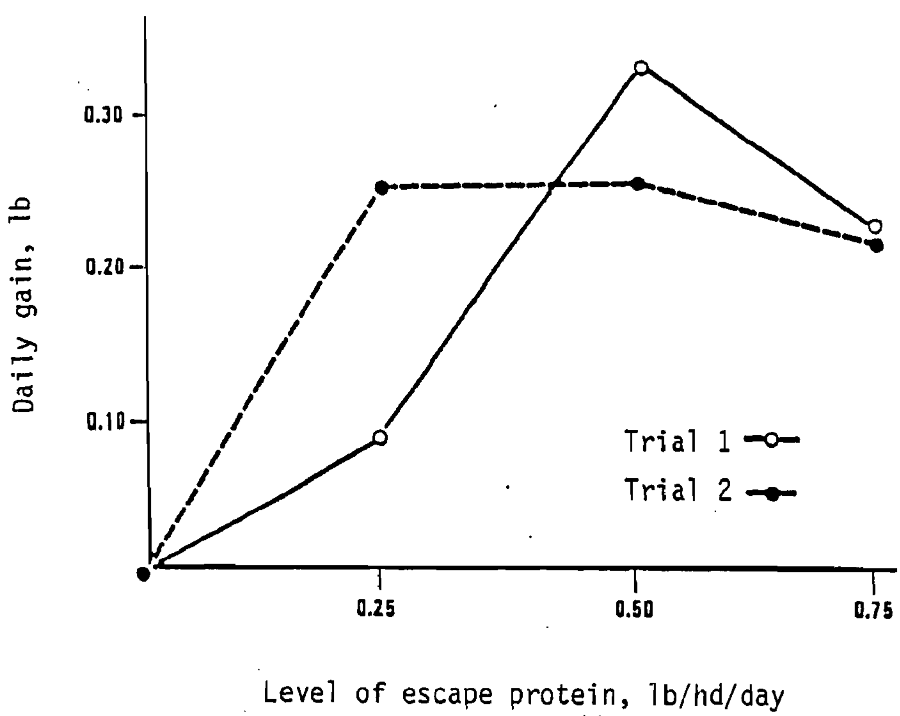


FIGURE 3. GAIN RESPONSE TO ESCAPE PROTEIN.

Magnesium (Mg)

From a cattle producers point of view the importance of Mg is its relationship to the serum metabolic disorder, grass tetany. The disease is also referred to as lactation tetany, grass staggers, and wheat pasture poisoning. Because of the low serum Mg of an afflicted animal, it is also referred to as "hypomagnesimic tetany". Grass tetany is a serious problem of grazing cattle in many parts of California. Early lush green grass and long periods of cold, foggy, or wet weather spell grass tetany. Grass tetany is a problem that strikes the cow under the stress of lactation or late pregnancy. This is especially a problem with grazing beef cattle where the first indication of grass tetany may be finding one or more dead animals. Older cows may be more susceptible to grass tetany because of the decreased ability to mobilize skeletal Mg with increasing age.

Several safe and practical means of preventing losses from grass tetany have been developed. Animals that develop grass tetany need immediate treatment. The most common treatment is an intravenous injection of at least 500 ml of a dextrose solution containing both Mg and Ca. Treatment can also include subcutaneous injection of 200 ml of a saturated solution of magnesium sulfate. Consult with your local veterinarian regarding recommended preparation and dose rates.

In a high risk or tetany-prone area, cows should be fed supplemental Mg. The recommended amount of Mg for cattle in California is 8 grams per head per day. An intake of 15 grams of Mg is desirable, but difficult to obtain. Supplements containing Mg should be palatable because grass tetany can cause anorexia and this in itself can be one of the problems in getting sufficient intake of Mg supplement. It is, therefore, essential in a prevention program to initiate measures before tetany season to insure the sufficient intake of Mg supplements. It is recommended that supplements containing Mg be fed at least two months prior to tetany season.

The success of cobalt (Co) pellets in providing supplemental Co led to the development of the Mg alloy pellet. These pellets last only one season. Some may be regurgitated and the rate of Mg release is variable. Therefore, pellets are not recommended at this time.

Selenium

Selenium deficiency is an economic problem and has been the subject of extensive research by U.C. livestock farm advisors. Current research is evaluating the effectiveness and pellet life of the ICI pellet versus the California pellet. This research is being conducted by U.C. livestock farm advisors in Lassen, Merced, and Santa Barbara Counties. To date, pellet life is about two years for both pellets.

The effects of particle size of Se on pellet effectiveness and life is being studied in Shasta County. Small, medium, and large particle sizes are being evaluated. Final analysis of the results from this study is a few years away.

Recommendation from over 7 years of pellet research for Se deficiency problems are:

- Pellet all cows and bulls.
- Repeat pellets every two years depending on local conditions.
- Pellet young cattle to be kept six months or longer.
- Calves born from pelleted cows have sufficient blood Se levels for three to four months after birth.
- Calves three months of age can be successfully pelleted.

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E. C. Loomis, Extension Parasitologist

Introduction

Hereford cattle at the Sierra Foothill Range Field Station (SFRFS) were selected for trials with Cooper's ear tags (ET) and other pesticide application methods for horn and face fly control:

SFRFS - 20 miles east of Marysville, Yuba County.

a. Bred heifers (62 hd), Cooper's double ET(Code 20), June 9, 1986.

b. Cows (60 hd), Deltox 0.25% spray on April 20, and Ectiban single ET tapes, June 10, 1986.

c. Bulls (7 mature, 15 yrlg.), Deltox 0.25% spray (1/2 gal/hd) on June 13, 1986, and Ivomec SQ on July 29th.

d. Cows (130 hd), treated on April 16 and 23 with Deltox 0.25% spray, and exposed to Warbex 1% dust bags July 27 to August 27, 1986.

Procedures

One observer made fly counts visually or with the aid of 10X50 binoculars or a 20X spotting scope. Counts were made of horn flies (*Haematobia irritans*) resting on one side of the body (withers, rib cage) and of face flies (*Musca autumnalis*) resting on the face and head. Counts were made in the morning hours on not less than 10 animals of each group.

Results and Discussion

A comparison of fly counts on the different herds under various chemical treatments is shown in Table 1 with graphic illustration of horn fly population trends shown in Figures 1-3.

Following application of Cooper's ear tags (Code 20) on June 9, the horn fly population on the 62 bred heifers was reduced to nil (99-100% control) for 12 weeks (6/9 to 9/9) except for a slight increase during the inspection on 8/18 (94% control); comparison of fly populations was made with the control cows (130 head) to August 5 after which time comparison had to be made against those flies on the registered cow herd (60 head) until the end of the trial on October 15 (Table 1, Fig. 1). Fly density on the bred heifers during

The horn flies proved more susceptible to Cyhalothrin than to Permethrin in the June 18 test; the flies were less susceptible to Cyhalothrin when a second test was made on July 2. These Cyhalothrin/Permethrin test results may be compared with those conducted on June 26 using horn flies at the Fresno State University Field Station where LD_{50-90} values were entirely different (CY = .00002-.0008; PERM = .0001-.0035).

Additional susceptibility tests were conducted on horn flies at U.C. SFRFS using the new 2-hour filter paper/petri dish test designed by Dr. C. Sheppard (Univ. GA) with results expressed in terms of $\mu g/cm^2$. Log probit regression levels for LD_{50-90} on Cyhalothrin, Fenvalerate and Permethrin are shown in the accompanying table:

Chemical	Date	LD_{50}	LD_{90}
Cyhalothrin	8-11	2.5	13.7
Fenvalerate	7-9	0.8	11.0
	9-17	10.5	100.
Permethrin	7-9	1.3	13.5
	8-11	12.	68.
	9-17	10.8	120.

The above results show initial susceptibility by flies to Fenvalerate and Permethrin (July 9th) with increased levels of tolerance to these compounds as the summer season progressed (August 11th and September 17th). Repeat tests for Cyhalothrin, unfortunately, were not conducted so it is impossible to venture an opinion on continued fly susceptibility to this compound aside from the negative possibility as indicated by continuous high levels of fly control on the Cyhalothrin eartagged bred heifers (Table 1, Fig. 1).

The author wishes to acknowledge the cooperation of and assistance by the following staff during the conduct of this study: Michael M. Connor, Superintendent, U.C. SFRFS, Nancy L. Martin, Staff Research Associate III, Dept. Ani. Sci., U.C. Davis-SFRFS, and Judy Owens and Charles Roudebush, Laboratory Assistants, Ext. Vet. Med. (U.C. Davis).

Table 1. Average Number of Horn (HF) and Face Flies (FF) per Head at Sierra Foothill Range Field Station, Yuba, Calif., 1986

Date	Bred Heifers (62 hd.)		Reg. Cows (60 hd.)		Bulls (22 hd.)		Control Cows (130 hd.)		Calves (40 hd.)	
	HF	FF	HF	FF	HF	FF	HF	FF	HF	FF
April			SP	(4/30)			SP	(4/16, 4/23)		
5/14	55	25	2	20			15	30		
6/2	85	4	25	15			10	15	20	10
	2ET20		1ETT(6/10)						1ETT(6/12)	
6/9	120	10								
					SP(6/13)					
6/18	0.3	0.8	35	3			55	6	35	0.3
6/24	0.2	0.3	25	2	30	6	115	0.6		
7/2	0.2	0.5	35	0.1	30	2	105^{DB}	0.4	120	2
7/9	0.1	0.1	60	0.2	110	1	125	0.2	85	1
7/15	0	0	35	1	190	1	340	0	130	1
7/22	0	0.1	15	0.1	200	0.2	185	0.1	145	2
7/29	0.5	0.1	25	0.1	245^{I}	0.6	135	0.4	205	1
8/5	0.4	0	75	0.2	45	0.4	130	0	Discontinued, mixed with another group untreated	
8/12	0.5	0	45	0.3	8	0.8	90	0.3		
8/18	5	0.3	140	0	25	0.3	85	0		
8/27	0.3	0.4	50^{IP}	0.1	20	0.2	50	2		
							Discontinued, to dry range.			
9/3	0.4^{TR_1}	2	25^{TR_2}	2	50	0.7				
9/9	7^{TR_1}	0.2	30	0.1	55	0.1				
$9/17^{R}$	0.6^{TR_1}	0	9	0	70	0				
10/6	2^{TR_1}	0.5	30	0.8	40	0.5				
10/15	5^{TR_1}	0	20	0	200	0				

SP: Deltox 0.25% spray on dates indicated
2ET20: Cooper's double EarTag (Code 20) applied.
1ETT: 1 Ectiban Tag Tape applied.
DB: Warbex 1% Dustbags.
I: Ivomec dewormer applied.

IP: Herd moved from dry range to irrigated pasture.
TR: Tags removed.
TR$_1$: Tags removed in Sept. and Oct. as heifers calved.
TR$_2$: Tags removed on 8/29.

FIG. 1. COMPARISON OF THE AVERAGE NUMBER HORN FLIES PER ANIMAL EXPOSED TO COOPER'S EARTAG-20 (——) AND TO OTHER TREATMENTS (– –), U.C. SIERRA FOOTHILL RANGE FIELD STATION, YUBA COUNTY, CALIFORNIA, 1986.

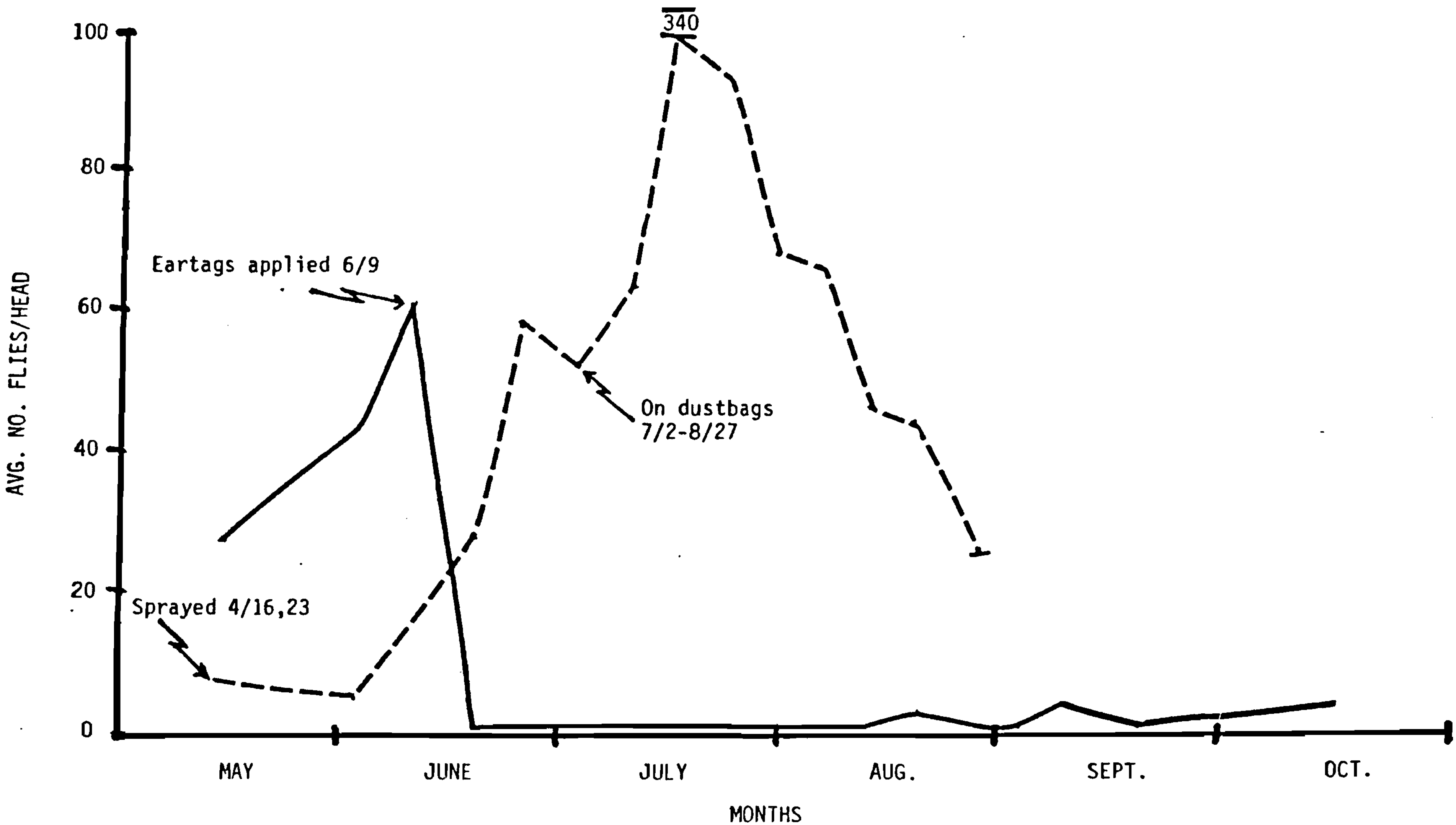


FIG. 2. COMPARISON OF THE AVERAGE NUMBER HORN FLIES PER REGISTERED COW EXPOSED TO DELTOX SPRAY AND ECTIBAN TAG TAPES (——), U.C. SIERRA FOOTHILL RANGE FIELD STATION, YUBA COUNTY, CALIFORNIA, 1986.

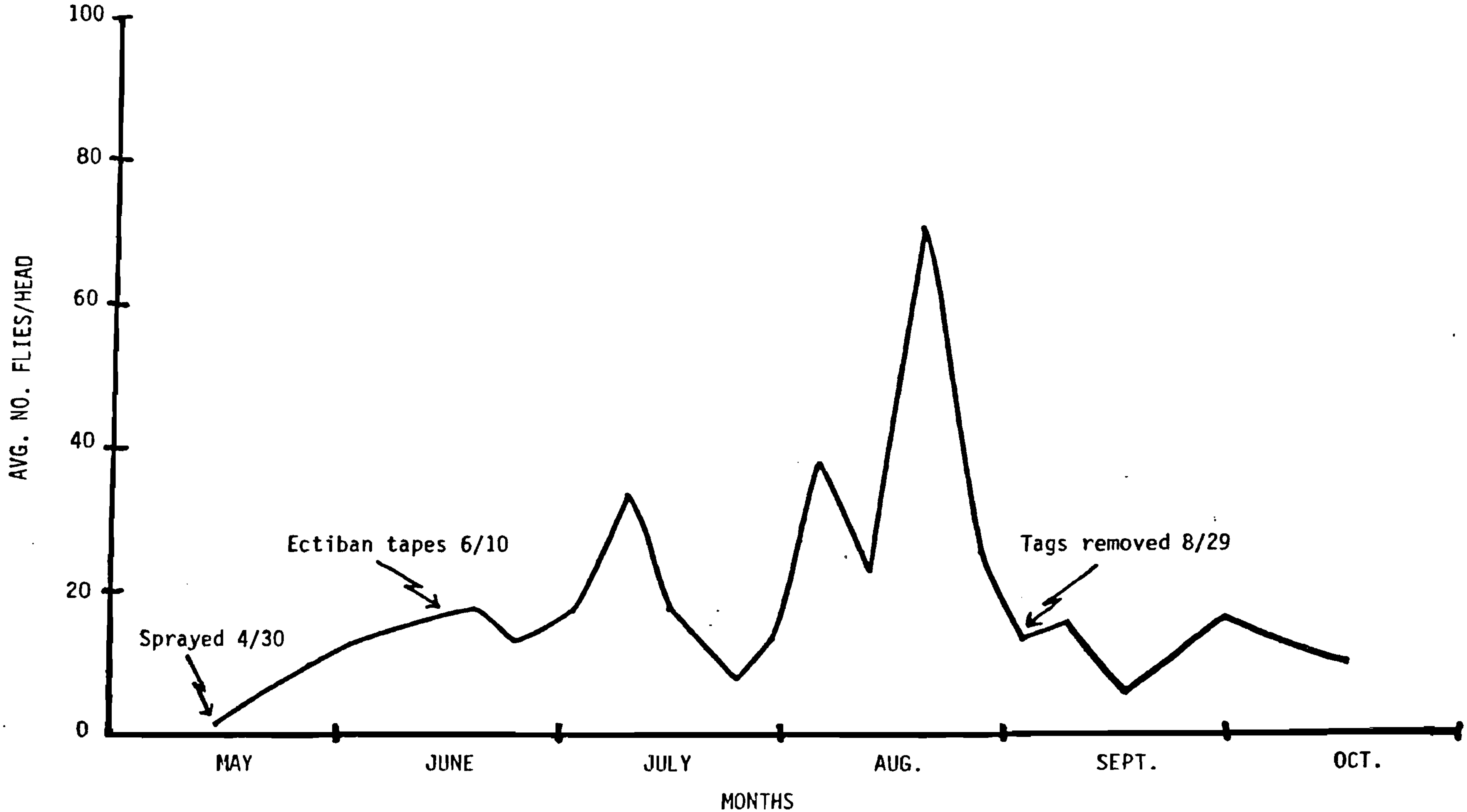
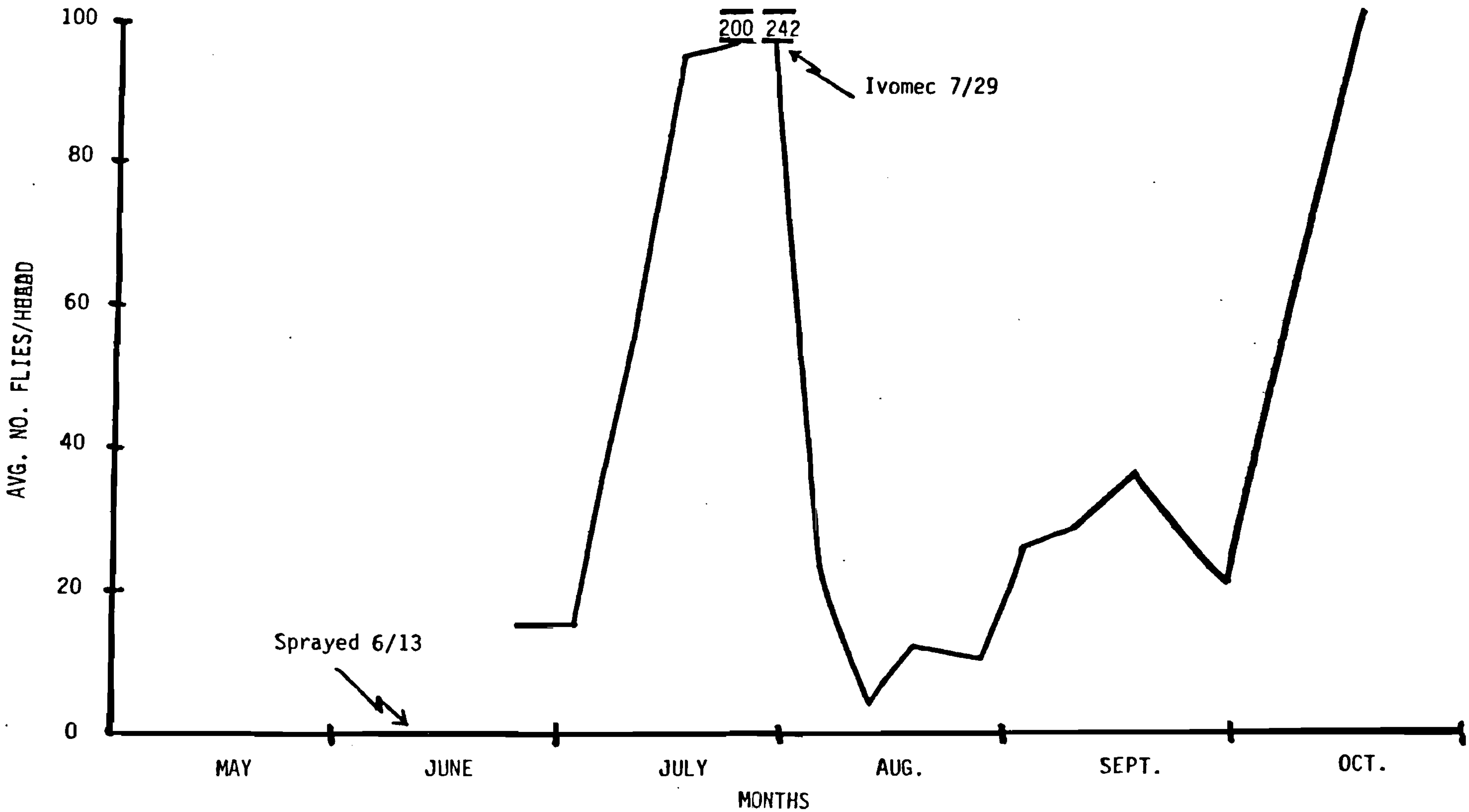


FIG. 3. COMPARISON OF THE AVERAGE NUMBER HORN FLIES PER BULL EXPOSED TO DELTOX SPRAY AND IVOMEC INJECTION (——), U.C. SIERRA FOOTHILL RANGE FIELD STATION, YUBA COUNTY, CALIFORNIA, 1986.



about 12 percent higher than English units.) Differences between treatments were largest in year one, the season immediately following fertilization and one with ample rainfall and a long plant growth period. Gains were significantly higher than control for all treatments. Variation between replications within a treatment and a diminished response to fertilization resulted in fewer significant differences in year two. In year three the lower rate of N treatment yielded significantly less than the control while the higher rate of phosphorus and sulfur yielded significantly more than any other treatment. In year four there were no statistically significant differences between any of the treatments. However, the numerically largest value occurred for the high PS level treatment.

Seasonal patterns. In Figure 3 another kind of data summary is shown, one which integrates values for ADG and forage level for all treatments across each of four full years and part of the fifth (1986-87). For ADGs, a general, linearly-rising trend was demonstrated for the period December to early May. Except for the exceptional year of 1982-83, ADGs declined precipitously by the end of May or early June, along with a rapid advance in plant maturity and peak values for forage accumulation. Forage levels from November to mid-March varied between years but were relatively stable across their seasonal time interval, while the period of rapid plant growth consistently began in late March or early April. Successively lower peak forage accumulation levels were observed over the three years. The within-season and year-to-year patterns shown in Figure 3 illustrate the behavior of this plant-grazing animal system, a thorough understanding of which forms a necessary basis for making livestock and grazing management decisions.

Economics. Table 2 presents an economic analysis of the fertilizer treatments for the first three years of the study. Important variables in determining relative profitability were: initial cost of treatment, levels of the PS-only treatments, stocking rate adjustments, and the general legume-enhancement response to P and S. Nitrogen, phosphorus and sulfur all needed to be supplied, with nitrogen provided either directly or through symbiotic fixation by PS-enhanced annual legumes. The two NPS treatments resulted in the greatest income above the controls for all three years. Income from the 60P66S treatment increased over the three years of the study.

The practice of adding stockers in late February or early March is contrary to normal local practice as most stocker cattle are purchased in the fall and early winter. Table 2 compares income with and without increasing stocking rate after the first week of March. With the cattle prices existing at the time of this study most treatments were more profitable if cattle were added at the beginning of this rapid spring growth period. Although in the economic analysis these additional cattle were "purchased" at the prevailing higher prices and therefore had narrower profit margins, they did contribute to a higher income per acre. If they had not been added, several of the treatments would have lost money when compared to the control.

The average initial stocking rates (late November - early December) were 8.2, 5.4, and 4.1 acres per head for 1982, '83, and '84, respectively. Three-year average maximum stocking rate with no upward adjustment after early March was 2.8 acres per head. The comparable value with seasonal upward adjustment was 1.0 acre per head, almost a three-fold difference.

Summary. For the geographic area and soil and vegetation types represented in our study, plant and animal productivity may be enhanced by either of two fertilization strategies. The first, and probably preferable, is to apply adequate levels of phosphorus and sulfur sufficient to stimulate legume production and symbiotic nitrogen fixation capability. The second strategy is to apply moderate levels of nitrogen together with adequate levels of phosphorus and sulfur, which will both increase plant production and have a somewhat greater effect during the fall and winter seasons. With either strategy, maintenance of effective stocking rates is critical to efficient forage to animal transfer and conversion. Finally, year-to-year variations in weather patterns can either enhance or negate management objectives and economic recovery of purchased resource inputs such as fertilizers. While weather constitutes a major determinant of system productivity, it consists of a set of variables for which, in contrast to cultivated and irrigated crop land, we have virtually no control.

Table 1. Stocking rates, stocking weights, and average daily gain for control and three treatment combinations for three representative weigh periods over three years.

	STOCKING RATE				STOCKING WEIGHT				FORAGE ALLOWANCE*				AVE DAILY GAIN				
Weigh date	ac/animal				lbs/ac				lbs/lb				lb/steer/day				
	Control	N-only	NPS	PS-only	Control	N-only	NPS	PS-only	Control	N-only	NPS	PS-only	Control	N-only	NPS	PS-only	
								1982-83 SEASON (196 days)									
1/7	3.26	2.84	2.00	3.11	161	187	265	171	9.4	10.1	11.6	9.9	0.64	1.14	0.90	0.95	
3/4	2.72	1.80	1.16	2.32	224	353	557	269	4.9	4.1	3.6	5.1	1.46	1.75	1.74	1.63	
5/6	2.77	1.81	1.16	2.33†	266	432	678	333†	7.9	4.7	3.3	10.2	2.16	2.31	2.18	2.38	0.33<
$\bar{X}$‡	3.45	2.82	2.32	2.88	216	308	432	342	6.7	5.3	4.9	7.4	1.45	1.64	1.68	1.74	0.18*
								1983-84 SEASON (190 days)									
12/20	4.08	4.08	4.08	4.08	117	117	117	117	3.9	4.2	5.1	4.4	1.01	0.90	0.95	1.05	
2/28	2.84	3.04	2.42	2.47	188	183	223	215	4.1	3.8	4.3	4.5	1.63	1.64	1.82	1.72	
5/8	2.13	2.20	1.66	1.68	333	331	450	433	6.1	5.8	5.2	5.9	2.45	1.98	2.31	2.51	0.40<
$\bar{X}$	3.29	3.37	3.05	3.07	204	204	252	243	4.5	4.3	4.5	4.7	1.51	1.62	1.70	1.60	0.11*
								1984-85 SEASON (183 days)									
12/20	4.08	4.08	4.08	4.08	127	124	127	125	6.2	6.2	6.4	5.7	0.82	0.74	0.93	0.86	
3/7	2.72	2.72	2.72	2.72	236	231	242	237	3.1	3.2	3.5	3.2	1.85	1.68	1.94	1.98	
5/9	1.33	1.48	1.09	1.21	539	473	651	600	2.8	3.1	2.5	8.0	2.01	1.83	1.98	2.22	0.37<
$\bar{X}$	2.71	2.76	2.63	2.67	299	274	339	319	4.1	4.1	4.2	4.7	1.44	1.36	1.61	1.62	0.11**
3 YR $\bar{X}$	3.15	2.99	2.67	2.87	240	262	341	301	5.1	4.6	4.5	5.6	1.47	1.54	1.66	1.65	0.11***

* Calculated as (pounds forage per acre)/(pounds animal weight per acre) using the average of two successive weigh periods.
† Stocking rate and stocking weight were increased after May 6, 1983 to 1.1 acres per animal and over 700 pounds per acre, respectively.
‡ Annual means are for eight weigh dates.
< $LSD_{0.05}$ values are for average daily gain, comparing fertilizer treatments in a weigh date row.
** $LSD_{0.05}$ values for annual mean differences for average daily gain in a weigh date row.
*** $LSD_{0.05}$ values for 3-year means for average daily gain in a weigh date row.

Table 2. Economic comparison of upward stocking adjustment about March 1 vs. no adjustment for the seven fertilizer treatments.

	STOCKING RATE (1)			GROSS INCOME (2)			PRACTICE COST (3)	GROSS PROFIT (4)			GROSS PROFIT ABOVE THE CONTROL		
TREATMENT	83	84 (head)	85	1982-83 ($/ac)	1983-84 ($/ac)	1984-85 ($/ac)	1982 ($/ac)	1982-83 ($/ac)	1982-84 ($/ac)	1982-85 ($/ac)	1982-33 ($/ac)	1982-84 ($/ac)	1982-85 ($/ac)
CONTROL up adj	12	15	24	56.35	40.77	43.75	.00	56.35	97.12	140.87	.00	.00	.00
CONTROL no adj	10	12	12	50.69	39.32	32.01	.00	50.69	90.01	122.02	.00	.00	.00
difference	2	3	12	5.66	1.45	11.74	.00	5.66	7.11	18.84	.00	.00	.00
40N up adj	16	17	20	78.19	43.52	37.16	16.80	61.39	104.91	142.07	5.04	7.79	1.20
40N no adj	11	11	12	62.37	40.83	30.45	16.80	45.57	86.40	116.85	-5.12	-3.61	-5.17
difference	5	6	8	15.82	2.68	6.71	.00	15.82	18.51	25.22	10.17	11.40	6.37
80N up adj	20	13	23	96.59	39.54	36.44	29.00	67.59	107.13	143.57	11.24	10.01	2.70
80N no adj	12	10	12	70.73	38.39	27.11	29.00	41.73	80.12	107.22	-8.96	-9.89	-14.80
difference	8	3	11	25.86	1.15	9.34	.00	25.86	27.01	36.35	20.20	19.90	17.50
40N+PS (5) up adj	26	20	33	126.95	54.09	55.57	31.90	95.05	149.14	204.71	38.70	52.02	63.84
40N+PS no adj	15	15	12	88.27	52.10	34.33	31.90	56.37	108.47	142.80	5.63	18.46	20.78
difference	11	5	21	38.68	1.99	21.23	.00	38.68	40.67	61.91	33.02	33.57	43.06
80N+PS (5) up adj	30	20	26	140.60	49.31	53.60	44.10	96.50	145.81	199.41	40.15	48.69	58.55
80N+PS no adj	18	12	12	100.92	45.69	37.72	44.10	56.82	102.51	140.23	6.13	12.49	18.21
difference	12	8	14	39.68	3.63	15.88	.00	39.68	43.31	59.18	34.02	36.20	40.34
30P33S up adj	12	17	20	67.61	43.71	39.45	15.00	52.61	96.32	135.77	-3.73	-.80	-5.09
30P33S no adj	10	11	12	60.44	42.18	31.39	15.00	45.44	87.63	119.01	-5.25	-2.39	-3.01
difference	2	6	8	7.17	1.53	8.06	.00	7.17	8.70	16.76	1.51	1.59	-2.09
60P66S up adj	16	22	33	89.92	50.34	66.13	25.45	64.47	114.81	180.93	8.12	17.69	40.07
60P66S no adj	11	13	12	70.91	45.31	40.92	25.45	45.46	90.77	131.69	-5.23	.76	9.67
difference	5	9	21	19.00	5.03	25.21	.00	19.00	24.03	49.24	13.35	16.93	30.40

(1) Number of head per 32.6 acre pasture; (2) Gross Income=(sale price x sale wt. x number sold) - (purchase price x purchase wt. x number purchased) Purchase and sale prices taken from Cottonwood sale yard; (3) Practice costs include costs of fertilizer materials, plus $4.25/acre application cost ($8.50 for NPS treatments), and interest charges at 12% for eight months; (4) Gross profit=gross income - practice costs; (5) Both N+PS treatments had only the 30P33S level of PS.

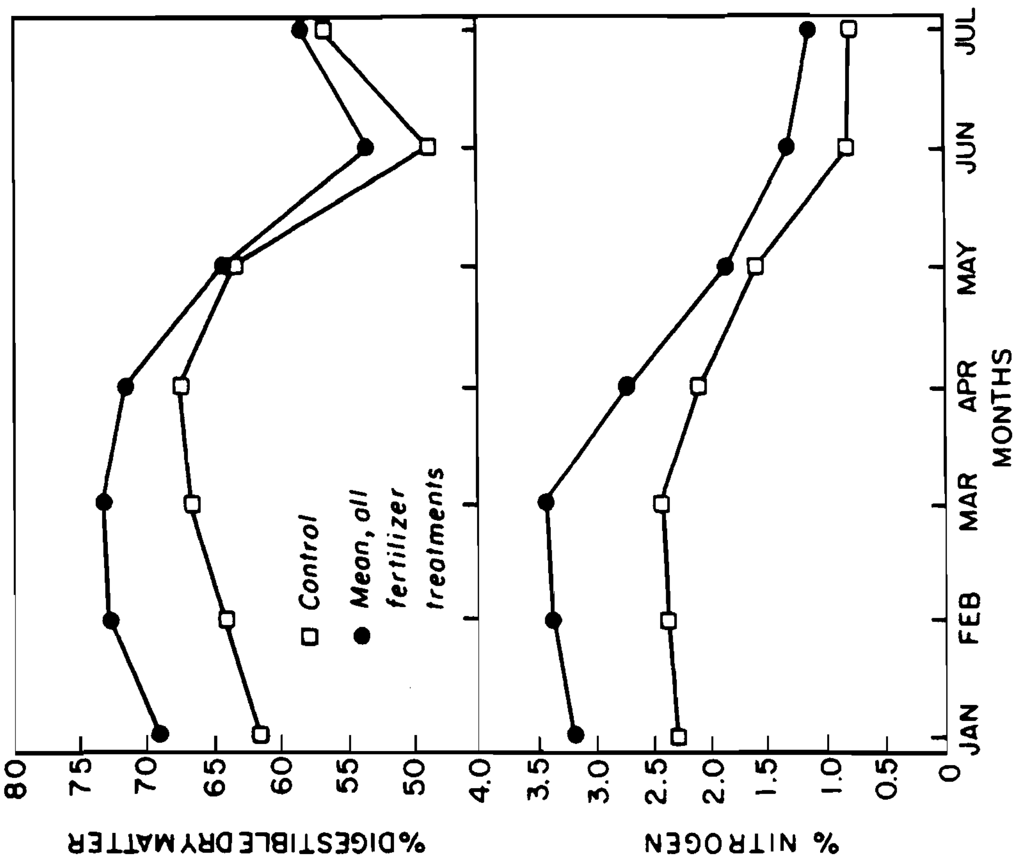


Figure 1. Percentages of digestible dry matter and nitrogen in samples from esophageally-fistulated steers grazing in control and selected fertilizer treatment fields during the 1982-83 season.

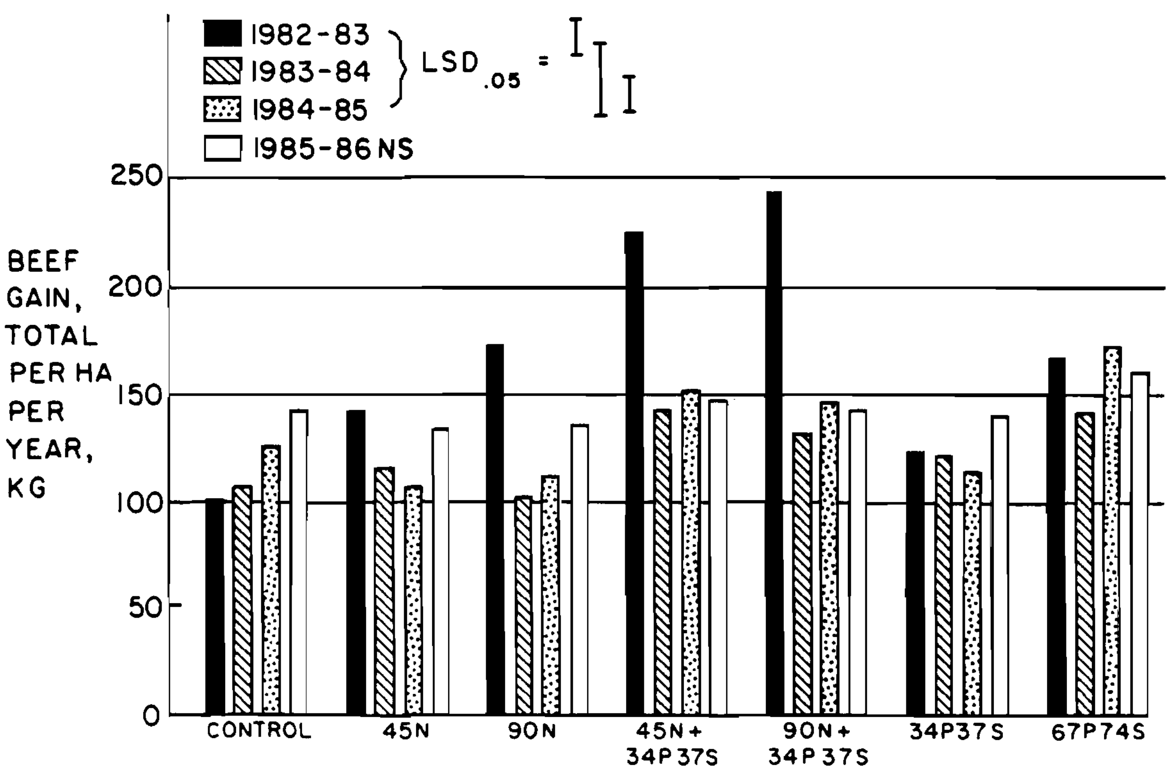


Figure 2. Yearly totals of steer liveweight gains per acre for four years for all fertilizer treatments. Values are in metric units (about 12% higher than English units).

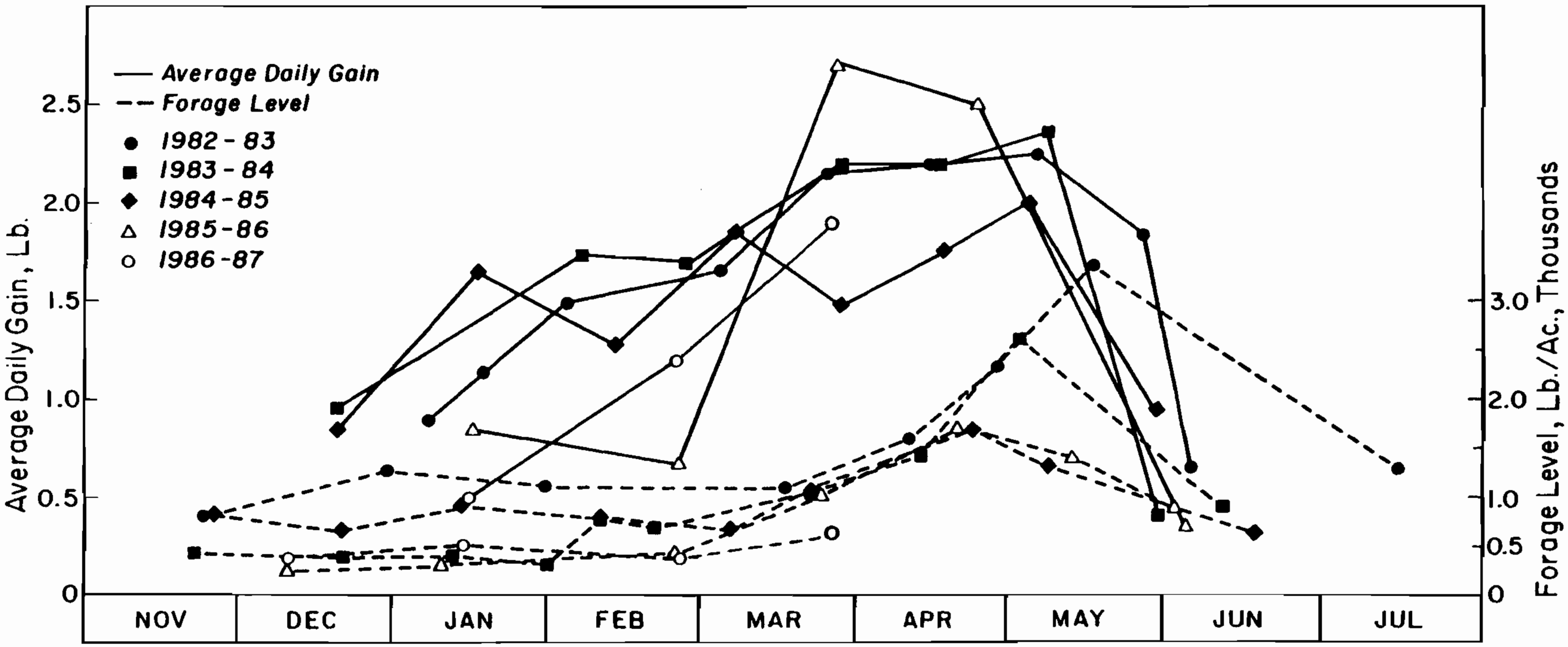


Figure 3. Seasonal patterns of average daily gains and levels of forage availability combined for all treatments (including control) for each of four full years and part of the fifth year.

TREATMENT METHODS FOR PINKEYE IN CATTLE

L. W. George

The effectiveness of topically applied furazolidone (NFZ), and subconjunctivally administered penicillin G for the treatment of infectious bovine keratoconjunctivitis IBK were compared to that of parenteral and combined parenteral oral therapy with oxytetracycline (OTC). The study was conducted at the Sierra Foothill Field Station using naturally infected calves. For the study, eyes of Hereford calves were examined 3 times weekly for 7 weeks. After 2 daily examinations on June 13 and 14, calves were randomly assigned to 1 of 3 groups. On June 17, affected calves of the first (n=35) second (n=35) and third (n=35) groups were respectively treated with topical NFZ, Parenteral OTC (20 mg/kg), and subconjunctival penicillin G (0.5 ml/eye). Calves of the 4th (n=33) group were separated from the other calves and were given oxytetracycline (2.0 gm/calf/day) as a feed additive, and were given a single intramuscular dose of OTC (20 mg/lb). In all of the groups, calves were not retreated unless the corneal ulcers recurred or worsened, or unless new corneal lesions developed. All of the calves were examined 3 times weekly until August 15th.

Calves treated with OTC had the best response to therapy, while those treated with topical NFZ had the poorest response. The response of the calves to the penicillin G was significantly poorer than that observed in the OTC treatment group. Calves blitz treated with OTC and fed OTC daily for 10 days had significantly fewer corneal ulcers during the observation period than calves of the other groups. During the treatment period, _M. bovis_ developed resistance to NFZ and penicillin G, but did not become resistant to OTC. Seemingly, OTC is superior to NFZ and penicillin G for the therapy of active IBK and when administered to all calves at the beginning of a pinkeye epizootic, will attenuate the course of the outbreak.

ELECTRONIC RECORDING OF GRAZING AND RUMINATION BEHAVIOR IN RANGE CATTLE

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Summary

A system that records and transmits data concerning times of occurrence of individual jaw movements of free ranging cattle is described. Each MICROPAK unit is capable of telemetering 48K bytes or 16,000 time-tags per hourly transmission. The data is transmitted hourly at a fixed time and contains the jaw movements of the currently logged hour as well as the previous two hours. This redundancy in data transmission allows for missed or garbled transmissions where the data would otherwise be lost. The received data transmission is logged directly to a computer hard disc using a custom program that logs only data and ignores extraneous line noise. The current system is capable of simultaneously recording the daily activities of seven cattle.

Introduction

Intake of forage is a major factor in determining the level of production from grazing animals. Profitability may depend to a large part on the grazing animal achieving as high an intake as is possible and so it is important to understand and quantify the factors involved. Two predominant aspects limiting intake are the pasture sward structure effects on the ability of the animal to satisfy its appetite, and the rate of disappearance of digesta from the alimentary tract (Freer, 1981).

Forage intake is the product of three components: weight harvested per grazing bite, number of grazing bites per minute and total time spent grazing. In essence the daily voluntary intake of food by grazing animals can be expressed in a mechanistic form as illustrated by Hodgson (1985).

GI = IB x RB x GT

GI (Grazing Intake
IB (Intake Bite)
RB (Rate of Biting)
GT (Grazing Time)

Using this type of approach, Chacon et. al., (1976) concluded that estimates of herbage consumption by grazing animals can be obtained from measurements of eating behavior. Intake per bite (mg of organic matter per bite) is estimated from esophageal fistulated animals using the technique described by Stobbs (1973), and is directly influenced by pasture sward height and herbage mass. Increasing tiller length increases bite size almost linearly, whereas rate of biting and grazing time decrease (Allden and Whittaker, 1970).

Grazing behavior is related to the quality of forage ingested, as voluntary intake decreases (Freer, 1981) and rumination time increases (Chacon et. al., 1976) as the digestibility of the feed declines and fibrosity of feed increases, Balch (1971) found that increasing fibrousness increased not only rumination time but eating time as well. He concluded that total chewing time (eating plus rumination), in minutes per kg of dietary dry matter, is a suitable index of the physical property of fibrousness.

Recording bite rate and grazing time has been done by various methods such as direct observation of the animal (Hull et. al., 1960), vibracorders (Allden, 1962; Stobbs, 1970) and grazing clocks (Jones and Cowper, 1975). Radio transmission of jaw movement data was done by Nichols (1966) by fitting a small transmitter and electrodes to record and transmit the electrical potentials of a sheep's jaw muscles. Tracing these jaw movements on a chart recorder made possible the separation of periods of grazing, rumination and idling.

Each of the previous methods makes it very difficult to analyse individual bites due to the massive number of jaw movements an animal makes daily. With the advent of inexpensive memory systems and microcomputers it is now possible to log, store and analyse vast amounts of data. This paper describes a system that has been developed to simultaneously record and time-tag individual jaw movements on up to seven free ranging cows and transmit this data to a computer for storage and subsequent analysis.

Materials and Methods

Electronic Equipment

Halter Transducer. The principle and basic construction of a transducer to monitor jaw movements was described by Penning (1983). Modifications of this design were made to allow for more rugged conditions encountered on the range. A transducer is made of layers of silicon with a central core of carbon granules. Stretching the transducer causes its electrical resistance to increase and relaxing it causes the resistance to return to normal. The transducer is attached to a cow halter in such a way that a jaw movement causes the transducer to stretch and then relax. Thus a jaw movement is indicated by a change in the electrical resistance of the transducer.

MICROPAK System. The MICROPAK system consists of a battery pack and data collection unit connected to the nose transducer, which are placed on a cow in a specially designed harness and halter arrangement. The MICROPAK is housed in a 23 x 30 x 8 cm aluminum case and weighs about 1.5 hg. An 18 cm flexible rubber duck antenna is mounted on the top center surface for optimum power radiation. Power is provided to the system from a six volt, 9.5 amp hour capacity lead-acid gel-cell battery. Typical operational lifetime of the battery between rechargings is about 21 days.

The transmitter is capable of telemetering 48K bytes or 16,000 time tags per transmission. Maximum range of transmitter to receiver in the field trial was approximately one-half mile. Each hourly transmission consists of not only the current hour of logged data, but in addition, the previous two hours' data as well. This redundancy in data transmission is to compensate for lost or incomplete transmissions. Therefore, there are three chances to collect each hour's data. Since a number of transmitters are used simultaneously, each has been allotted a specific time period during each hour for transmission of data, based on the particular number entered on initialization. With a full 48K memory to transmit, the time required for each transmitter to complete transmission of the stored data was calculated at eight minutes, allowing a maximum of seven transmitters to be used (Figure 1).

A change in the electrical resistance of the transducer causes a voltage change in the current running to the MICROPAK. When this occurs it is stored in memory based on the time of occurrence, or time tagged. Time-tags are stored in the data bank as one-hundredths of a second (hh), second (ss) and minute of the hour that they occurred.

Data Format: hh ss mm
Example: 75 49 37
(37 minutes, 49.75 seconds past the hour)

Receiver and Computer. The transmission is received by a field receiver which in turn sends the data along a 1800 meter cable to the field station headquarters where the computer is located. It is estimated that the cable could be extended another 2000 meters and maintain effective data transmission. At the computer end of the cable is the local receiving station which provides power for the field receiver and receives the data and routes it to the computer where it is logged.

The computer used is a DEC Rainbow 100 connected to the local receiving station via cable to the computer communication port. Data is logged at 1200 baud using a specially written program that looks for an opening sequence, holds that data in memory until a closing sequence is seen, then writes the captured data to a 20MB hard disk. Floppy disks are used to store the data for transport to a mainframe computer for analysis.

Field Trial

The field trial is designed to determine if varying supplementation levels have an effect on the grazing and rumination behavior of cows grazing mature range, and if these behavior patterns can be detected using the jaw movement data-logging telemetry system. A latin square design was used in which three supplementation levels were applied in sequence to each cow. Two age groups of six cows each were used. All cows were trained prior to the trial to feed from specific gates on the supplement trailers described by Morris and Delmas (1982).

The correlation between the activities recorded by the portable unit and observed directly on animals has been very good indicating the validity of the procedure. See Fig. 2 and Table 1. An example of a single 24 hour recording on one animal is shown in Figure 3.

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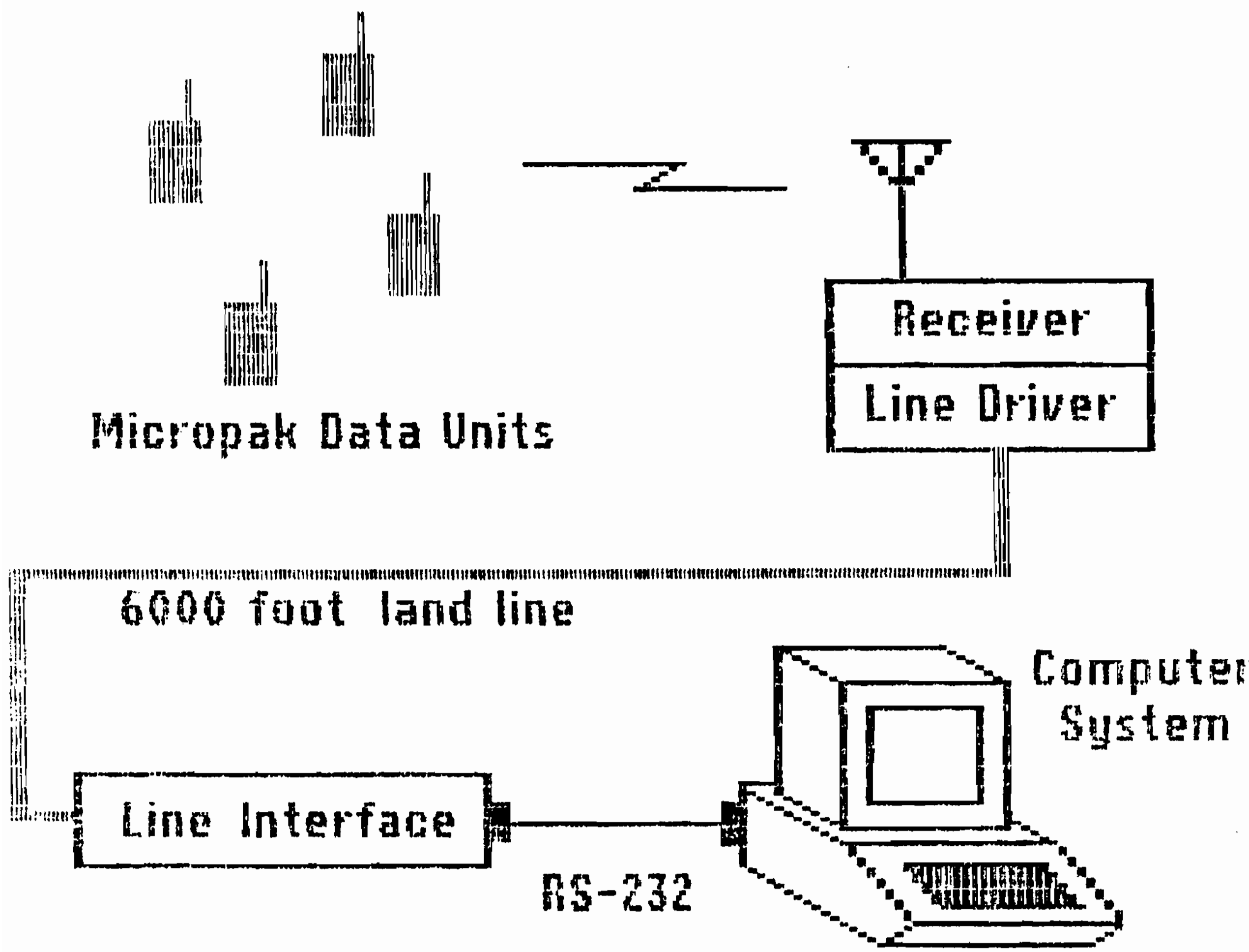
FIG. 1


Receiver
Line Driver
Micropak Data Units
6000 foot land line
Computer System
Line Interface
RS-232

On the basis of the last two harvests Verde kleingrass was most productive followed by Lehmann's lovegrass, sand lovegrass and switchgrass. NK Pasto Rico bermudagrass, Pensecola bahiagrass and boer lovegrass were least productive of the warm season grasses for the last two harvests.

Table 1. Total forage yield for the warm season grass trial at U.C. Sierra Foothill Range Field Station harvested monthly from June - September 1986.

Common Name	Variety	Yield (lbs/a)	
Switchgrass	Kanlow	9620	A
Indiangrass	Osage	9216	AB
Sand Lovegrass	Bend	8684	ABC
Sideoats Grama	El Reno	8512	ABC
Lehmann's Lovegrass		7768	BCD
Little Bluestem	Aldous	7760	BCD
Kleingrass	Selection 75	7720	BCD
Dallisgrass	Common	7572	BCD
Big Bluestem	Kaw	7200	CDE
Boer Lovegrass	Catalina	7144	CDE
Bermudagrass	Coastcross 1	6700	DEF
Bermudagrass	Tifton 68	6572	DEF
Bahiagrass	Pensecola	6108	DEF
Bermudagrass	NK Pasto Rico	5520	EF
Limpograss	Bigalta	5432	F
Tall Fescue	Fawn	3760	G
Orchardgrass	Akaroa	3476	G
Perennial Ryegrass	Ariki	2444	G

Yields followed by the same letter are not significantly different (p=0.05)

Table 2. Total forage yield for the last two harvests of the warm season grass trial at U. C. Sierra Foothill Range Field Station in August and September 1986.

Common Name	Variety	Yield (lbs/a)	
Kleingrass	Verde	4450	A
Lehmann's Lovegrass		4218	AB
Sand Lovegrass	Bend	3976	ABC
Switchgrass	Kanlow	3958	ABC
Sideoats Grama	El Reno	3718	ABCD
Kleingrass	Selection 75	3642	ABCD
Bermudagrass	Coastcross 1	3636	ABCD
Indiangrass	Osage	3564	ABCD
Laurisagrass		3454	ABCD
Limpograss	Bigalta	3186	ABCD
Little Bluestem	Aldous	3140	ABCD
Bermudagrass	Tifton 68	2990	BCDE
Big Bluestem	Kaw	2950	BCDE
Dallisgrass	Common	2908	BCDE
Boer Lovegrass	Catalina	2656	CDE
Bahiagrass	Pensecola	2536	DEF
Bermudagrass	NK Pasto Rico	2468	DEF
Tall Fescue	Fawn	1770	EFG
Orchardgrass	Akaroa	1304	FG
Perennial Ryegrass	Ariki	804	G

Yields followed by the same letter are not significantly different (p=0.05).

November 30, 1986

Statewide Range Improvement. The use of controlled burns, mechanical clearing and re-seeding for range improvement by vegetation-type conversion (VTC) has been prominent in California for over forty years (Arnold et al., 1951). Figure 1 was taken from the last published Brushland Range Improvement Report (Calif. Div. of Forestry, 1978), and shows the extent to which VTC has been practiced. A large measure of this activity occurred in the 20-year period between 1950 and 1970. Historically, attention usually was given to achieving as complete of degree of conversion (removal of woody vegetation) as possible, in order to provide maximum opportunity for growth of resident and introduced herbaceous forage and to minimize or eliminate regrowth or reinvasion of (primarily) resprouting shrubs and trees. The location for, and timing of addition of, the Sierra Station to California's Agricultural Field Station system had, therefore, obvious and marked influences on its development.

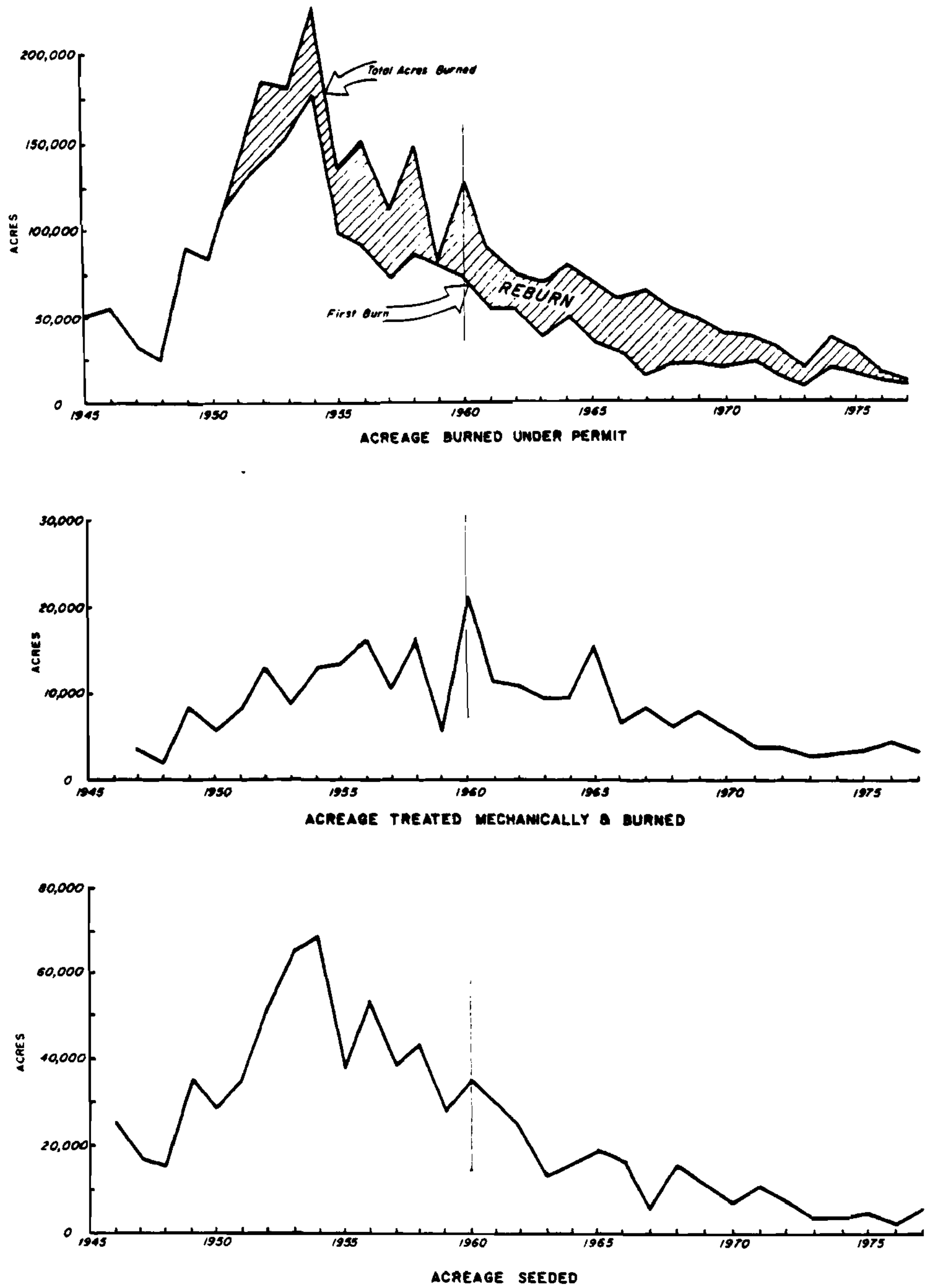


Figure 1. Statewide activity in controlled burning, pre-burn mechanical treatment, and re-seeding, 1945-1977, inclusive. Source: Brushland Range Improvement--Annual Rept., 1974-1977. State of California Department of Forestry, September 1978. 17 pp.

Evolution of Type Conversion at the Station

Forbes Area. Initially, an area of 900 acres was scheduled for complete conversion. Herbicidal injection of the oak trees was done over a 3-year period, 1961-1963. A summer controlled burn was done on July 24, 1968. No immediate seeding or fertilization was done. Follow-up control of resprouting shrubs (mostly poison oak) was done over a four-year period, 1969-1972, using a mixture of 2,4-D and 2,4,5-T. Labor required for sprout control was 1.8, 1.5, 1.1 and 0.3 man hours per acre for the four years. Save for a few digger pines in a limited area, virtually no shrub or tree vegetation exists on the present 520 acres of the Forbes Hill F1-11/F1-44 research area. Introduction of improved range plants (1971-1974) was done by use of Bud Kay's range drill and establishment procedures. The legume mixture consisted of two cultivars of rose clover, seven cultivars of subterranean clover and, in some fields, either "Jemalong" annual medic or Perlagrass was added to the legume mix. A moderate amount of single superphosphate was placed in the drill rows. Good stands of both rose and sub clovers subsequently developed, but the medic and Perlagrass have disappeared from the area. Figure 2 (Part A) shows a recent aerial view of the Forbes area.

Figure 2. Aerial view of three approaches to vegetation-type conversion at the UC Sierra Foothill Range Field Station. A: Forbes Hill; completely cleared, with woody plant regrowth completely controlled. B: Porter; scattered trees left in a random pattern; woody regrowth controlled. C: Scott; prescription manipulation as described on page .

Porter Area. A second, 400 acre area was converted in much the same manner over the period 1965-1971. Here, in contrast to the Forbes site, it was intended to leave approximately 10-12 oak trees per acre untouched. Again, chemical treatment was used to kill trees (1965) but substantial additional chain saw work, brush piling and brush pile burning was done to establish reliable and adequate perimeter fire lines. Final preparation, an area controlled burn, follow-up spraying, plus ground and aerial seeding was done in 1970. Some spot reseeding of open areas in two sub-fields (comprising 77 acres of the 400-ac total) was done in 1971. Chemical resprout treatment was done during the years 1971-1976. In summary, the overall cost of labor for tree killing, perimeter fire line preparation, burning and all seeding and reseeding was $37.50 per acre at cost levels for the years in which the work was done. Total cost of follow-up resprout control (1971-1976) was $17.40 per acre. If the rather specialized research needs of fencing, water development and water distribution are not counted, the total cost per acre for this program was $55 per acre. The area is shown as Part B of Fig. 2. The eventual tree density was less than desired as some trees were lost by fire damage. The reseeding done by range drill included a legume mixture similar to that used on Forbes Hill to which was added a mixture of the summer-dormant perennial grasses Hardinggrass, Perlagrass, and Palestine orchard grass. In areas with a combination of deep soils and northerly-easterly facing slopes, both sub clover and the perennial grasses formed excellent stands.

Scott Area. In December of 1977 funding became available from Systemwide Administration of the UC Division of Agricultural Sciences for a Station-wide program of resource augmentation (including additional land clearing and irrigated pasture development), the primary goal of which was to increase the overall livestock carrying capacity of the Station to an extent sufficient to permit a greater diversity and improved quality of range, livestock, wildlands, and watershed research. A committee, formed to guide the development program, met early in 1976 and, using a 53-acre parcel of land designated Haworth H-7, established a set of criteria to be applied for all additional field-scale type-conversion on the Station. Concurrently, a more complete analysis of the environmental impacts from application of intensive range improvement practices was done as a Master's thesis research project, later published as a UC Water Resources Center Report (Albin-Smith and Raguse). The results of this revised approach are evident in the area labelled "C" in Fig. 2 (Scott area). A major departure from previous procedures was to replace controlled burning by contract sale of oak trees for firewood to a commercial wood cutter. Terms of this contract included 1) cutting stumps as near to ground level as possible, 2) treating the cut stumps with an herbicide to control resprouting, 3) piling limbs and brush to form quail cover and to facilitate burning of debris at some later date, and 4) refrain from use of trucks or other heavy equipment at time and/or places with potential for soil structure damage or erosion. Attention was directed to accommodation of natural variations in the landscape and to current or potential uses or values other than livestock grazing.

New Criteria for Type Conversion. As a minimum, the UC Sierra Foothill Range Field Station now employs the following criteria:

1. Leave strips of all woody vegetation in natural drainageways to reduce erosion.

2. Leave all woody vegetation on rocky outcrops.

3. Leave scattered groups or corridors of trees (including all age-classes present) for aesthetic values, wildlife habitat, and livestock shade.

4. Use appropriate special conversion measures when specific bird and/or mammal wildlife management objectives exist.

5. Appropriately modify conversion when the area is part of a visually sensitive landspace.

6. Avoid clearing of slopes in excess of 30-40 percent to minimize erosion hazard, except as needed to aid in livestock surveillance and handling.

7. Completely clear areas best suited for range or pasture related agricultural operations (e.g., reseeding, fertilization, agroforestry, irrigation).

Indirect Impacts of Vegetation Removal on Wildlife.

Wildlife habitat, in an area used for livestock grazing, is altered by VTC when it changes botanical composition of the vegetation and its three-dimensional profile. Removal of the oak/pine/shrub overstory to maximize herbaceous forage for livestock grazing reduces available cover and forage. In general, both cover and nutritional needs for deer and other game species can be satisfied by managing for mixed-age seral and mature plant series, creating habitat interspersion (Salwasser 1976). Vegetation manipulation, therefore, has potential as a positive wildlife habitat improvement tool.

Advantages to Leaving Woody Vegetation in Place.

Brush and tree eradication on foothill range also removes the roots of woody vegetation. These constitute a major subsurface stabilizing element of a slope. VTC also amplifies the impacts of precipitation and wind on the soil surface. The opportunity to avoid future soil loss, gully formation, and off-site siltation problems should provide adequate incentive for retaining groups of trees on steep hillsides, on rocky outcrops, or in natural drainageways, as well as for exercising good judgement and care in construction of access roads and trails (Albin-Smith and Raguse).

There are clear differences of opinion among researchers as to the direct and/or secondary benefits (e.g., higher nutritional quality of forage, more favorable growth environment) of either leaving or removing deciduous oaks, blue oak (Quercus douglasii H. & A.) in particular. There have been only a few studies done on the relationship between oaks and range forage production (e.g., Holland and Morton 1980; Kay and Leonard 1980; Murphy 1980). Those which have been done have used somewhat different experimental approaches or have been done in geographically-different areas. Current and future research conducted under the new Integrated Hardwood Range Management Program should do much to help provide the information base needed for California.

Conclusions

A program of vegetation-type conversion may have several objectives, only one of which may be increase of range forage to support livestock production. Along with increasing societal concerns about maintenance of environmental quality and wise management of renewable natural resources, complete type conversion has evolved to selective, prescribed manipulation of woody vegetation to maintain the natural mosaic pattern of the landscape.

The presently-recommended approach to VTC on foothill blue oak grass-woodland, as employed by the UC SFRFS seems to be a valid compromise between the the two extremes of accepting little or no forage production under a dense canopy of trees and brush vs. complete conversion with total suppression of woody plant regrowth.

The UC Sierra Field Station's experiences in an ongoing vegetation-type conversion program will aid in development of a more universally acceptable approach to improving livestock production without unduly compromising aesthetic values and natural resources conservation needs.

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stage height recorder. The almost continuous hydrograph record has been reduced and entered into a computer data base. Annual, monthly, and daily discharge is computed using this information.

Two rain gauges and rainwater sampling equipment are also in place for measurement of rainfall amount, intensity, and water quality. One rain gauge is located in the study area on a ridge that flattens out between the two watershed flumes. The second is installed on field F1-24 of the adjacent Forbes' drainage. Rainwater is analyzed for suspended solids, pH, EC, total alkalinity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, PO_4^{3-}, SO_4^{2-}, and NO_3^{-}. All rain fall data is reduced and tabulated for the period of study.

Automatic water samplers are installed upstream from the waterflow gauges in each watershed to collect periodic water samples. During the rainy season, the samplers take a water quality sample every two hours from the center of each stream near the bed. Fewer samples are taken during the non-rainy periods. Conductivity and pH are measured on all samples. Selected samples which represent the rising, peak, and falling phases of a runoff event are filtered through an 0.45 μm millipore filter to determine suspended sediment concentration. The filtered samples are analyzed for total alkalinity, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, PO_4^{3-}, SO_4^{2-}, and NO_3^{-}. During non-storm periods, additional samples are similarly analyzed whenever there is a change in measured conductivity. Both the suspended sediment concentration and associated EC have been entered into a computer data base for use in correlating these with discharge and for generating a sediment rating curve.

In January 1984 oak removal began in Watershed S1 and in July removal began on Watershed S2. Type conversion is being done by station personnel under the supervision of Mike Connors, Field Station Superintendent. During the period of study, 2,189 trees were harvested on 65.4 acres of the study area. Oaks were harvested on about 43% of S1 and 26% of S2. Most of the cutting on S1 occurred during the period 1/17/84 to 4/26/84 when 831 trees were felled on 28.4 acres. An additional six trees were removed during the period 4/1/85 to 5/15/85. There were three periods of cutting on S2. A total of 1352 trees were cut on 37 acres. The first 880 trees were cut between 7/22/84 and 8/16/84; the second cut removed 416 trees from 4/1/85 to 9/30/85; and 56 additional trees were cut between 4/26/86 and 5/26/86. Oaks are still being harvested in watershed S2.

We are also looking at "storm events" as units of observation and will be fitting a non-linear equation to the data for volume of storm runoff and peak runoff rates for calibration of the Modified Universal Soil Loss Equation (MUSLE). In 1977, Williams and Berndt, published the MUSLE, $Y = 95\ (Q * qp)^{0.56} *K*C*P*LS$, for predicting single-storm sediment yield. The model modifies the USLE (Wishmeier and Smith, 1978) by replacing the rainfall energy factor (R-factor) with a term for runoff intensity and using a weighted KCPLS. The MUSLE energy factor is a function of the product of Q, the storm runoff volume in acre-feet and qp, the peak runoff rate in ft^3/s; KCPLS is modified by calculating a weighted average value for each factor based on the percentage area of the watershed occupied by each soil, slope group or cover type. K is a soil erodibility factor, C a cover factor, P an erosion control factor and LS is a topographic factor.

We will compare the predictive capacity of this model to actual measured sediment yields of the watersheds using both the published form of the model and our calibrated version. The accuracy of the published model will be compared to the equation derived using our watershed data. We will also test the sensitivity of the model to oak management by examining the KCPLS factors.

A sediment-rating curve was generated for computing sediment yield as a function of runoff volume for the watersheds. The curve relates the sediment concentration (C_s) to runoff (cfs). An estimating curve was needed because there are only a limited number of C_s values recorded for many of the cfs points recorded. All C_s and cfs data were used to estimate the curve. The "rating curve" is then used to estimate C_s from cfs for all unmeasured points. Estimated C_s values are used along with measured cfs values to calculate annual sediment yield. However, measured C_s values are used where they exist when determining individual storm sediment yield.

Both simple linear, and second and third degree polynomial regressions of C_s on cfs are done using SAS programs to estimate the curve. The SAS REG and UNIVARIATE procedures are used to test for normality of both C_s and cfs data (Afifi and Clark, 1984). SAS REG plots both residuals and predicted values. SAS UNIVARIATE provides normal probability plots of the residuals to decide whether the data approximate a normal distribution. Cook's Distance (D) statistic is calculated for residuals to determine the influence of individual observations (Neter et al, 1983). Although examination of residual plots may uncover potential outliers, the effect of certain observations on the fitted regression equation may not be obvious from the plots. The magnitude of this influence can be examined by comparing the regression with another equation derived from the data after the one observation has been deleted.

The above procedure will also allow us to correlate sediment concentration, storm runoff and EC. We can also determine the effect of oak management on discharge and sediment yield relationships. Discharge and sediment yield have been correlated with the sequence of vegetation type conversion to determine cause and effect relationships. Data collected prior to type conversion (pre-cut) is being used as the "control" watershed data to which the post-type conversion (post-cut) is being compared.

Results

Hydrologic and Sediment Yield Data. Rainfall, runoff and sediment yield for 6 water years (Oct. 1 through Sept. 30) cover a wide range of precipitation amounts (Table 1). The average annual rainfall for the period 1980-86 was 31 inches. Rainfall varied from 18 inches in 1984-85 to 47 inches in 1981-82. In 1984-85, the driest year of record, the small S1 watershed did not begin to have measurable outflow until mid-November. Two years of record, 1981-82 and 1982-83 received above average rainfall.

The average annual runoff was 12 inches over the 64.8 acre S1 drainage area and 17 inches over the 254.4 acre S2 drainage area. Runoff on S2 may be higher than on S1 because it is larger, runs continuously, and has several springs which run all year. The average discharge from S1 is 34% of the measured rainfall (R_o/F_f), whereas, S2 releases 52% (Table 1). Runoff tends to increase linearly with rainfall. However, the amount of runoff discharged in 1982-83 is much higher than average, 60% on S1 and 80% on S2; and almost 25% higher than that during the highest rainfall year. This may be the result of a high rainfall year compounded by a high water table from the very wet previous year.

The sediment yield on S1 remains relatively stable regardless of rainfall or runoff variability (Table 1). S1 averages .3 short tons of sediment per year, and may be reaching the stream's carrying capacity at this amount. The 1984-85 sediment yield for S1 appears inconsistent with the other data. Although it is the driest year and runoff is relatively low, the yield is high relative to other years. This may be due to a sampling error on 2/8/85. A relatively high sediment concentration was measured when all other factors would indicate a much lower amount should have been measured.

Table 1. 1980-86 Rainfall (R_f), Runoff (R_o), Runoff - Rainfall Ratio R_o/R_f, and Sediment Yield for Schubert Watersheds, S1 and S2.

		S1			S2		
Year	Rainfall (inches)	Runoff (inches)	R_o/R_f	Sediment Yield (short tons)	Runoff (inches)	R_o/R_f	Sediment Yield (short tons)
1980-81	21	1	.05	.04	4	.19	.2
1981-82	47	17	.36	.2	27	.57	5
1982-83	40	24	.60	.3	30	.80	4
1983-84	29	12	.41	.2	14	.48	7
1984-85	18	3	.17	.6	7	.39	1
1985-86	33	14	.42	.2	20	.64	47
Total	188	71	--	1.5	102	--	74
Average	31	12	.34	.3	17	.52	12

Watershed S2 sediment yield is more variable ranging from .2 to 47 short tons per year. Although the average sediment yield is 12 short tons, the two highest rainfall-runoff years, 1981-82 and 1982-83, produced only an average 5 short tons per year. The highest yields were produced during the nearly average rainfall years. Sediment yield in 1983-84 was 17 short tons and in 1985-86, 47 short tons which is almost 65% of the total produced during the entire 1980-86 period. During a six day interval from February 14-19, almost 1/3 of the total rainfall for 1985-86 and almost 75% of the month's rainfall occurred which may account for the high yield. Almost 100% of the annual sediment for 1985-86 was produced at this time. Rainfall in 1983-84 appears as evenly distributed as that in 1981-82 and 1982-83 with no periods of intense storm activity to account for the relatively high yield.

Effects of Vegetation Management. 1984-85 was the first full year of runoff and water quality data since oak removal began on watersheds S1 and S2. The ratio of runoff to rainfall (R_o/R_f) for both watersheds during the post-cut year (1985-86) is 7% greater than the ratio for the pre-cut year 1981-82 which is the highest rainfall year (Table 1). Comparing low rainfall years suggests that the removal of oaks may have increased water yield even in dry years. For the two watersheds, the amount of runoff relative to rainfall during the post-cut year 1984-85 was more than double the amount during the pre-cut year 1980-81.

A comparison of average water flow for 2 years before harvesting (pre-cut, 1980-81 and 1982-83) to 2 years after harvesting (post-cut, 1984-85 and 1985-86) indicates an increase in the amount of runoff relative to rainfall after harvesting (Table 2). Although the pre-cut average annual rainfall is 31% more than the post-cut average, the ratio of runoff to rainfall after cutting is almost 7% greater than the ratio: for the years before cutting on S1 and S2.

Table 2. Average Rainfall (R_f) and Runoff (R_o) for Pre (1980-81 & 1981-82) and Post (1984-85 and 1985-1986) Harvest Years.

	Rainfall	Runoff S1	Runoff S2
	inches		
Precut	34	9	16
Postcut	26	9	14
		R_o/R_f	
Precut		.29	.47
Postcut		.35	.54

The average runoff relative to rainfall is lower for the post-cut years when an additional year, 1982-83, is added to the pre-cut average (Table 3). The ratio of runoff to rainfall for the years after cutting is 4% less for S1 and 2% less for S2 than for the years before cutting, indicating that oak harvesting had little effect on runoff. Additionally, in both comparisons, pre and post-cut averages for the ratio of runoff to rainfall (Table 2 & 3) are very close to the six-year average (Table 1) and are therefore, not statistically different.

Table 3. Average Rainfall (R_f) and Runoff (R_o) for Pre (1980-81, 1981-82 & 1982-83) and Post (1984-85 & 1985-86) Harvest Year.

	Rainfall	Runoff S1	Runoff S2
	inches		
Precut	36	14	20
Postcut	26	9	14
		R_o/R_f	
Precut		.39	.56
Postcut		.35	.54

Water Quality Data. There is little difference in water quality between pre and post-cut years which can be attributed to oak harvesting in watershed S1 (Table 4). By February, concentrations were essentially the same, and this continued in March. Unlike the other nutrient concentrations, NO_3 was high throughout 1984-85 compared to 1983-84 and PO_4 was the same three out of four months. In all months, the concentrations are close to the lower limits of detection. Similar data have not been calculated for watershed S2.

Table 4. Monthly mean concentrations for water quality parameters for watershed S1 in 1983-84 (pre-cut) and 1984-85 (post-cut).

Month/Year	pH	EC	SS	ALK	Ca	Na	Mg	K	Cl	SO_4	NO_3	PO_4
		umho/cm	------------------- mg / L -------------------									
Nov. 83-84	7.7	98	28	100	11.6	5.4	8.0	1.1	4.1	3.2	1.5	0.0
84-85	8.0	360	2	152	30.9	19.6	27.2	0.9	18.6	23.8	31	0.4
Dec. 83-84	7.7	87	48	60	10.2	6.0	7.7	0.9	2.9	2.9	0.6	0.01
84-85	8.0	192	2	128	20.5	9.3	16.4	0.6	4.9	5.1	2.3	0.01
Feb. 83-84	7.8	125	40	100	15.1	5.7	11.5	1.4	3.8	3.0	0.5	0.01
84-85	7.9	133	40	92	15.5	6.9	11.9	0.7	3.4	3.4	0.8	0.01
March 83-84	8.0	177	23	115	17.1	8.8	23.4	0.6	4.6	2.5	0.0	0.03
84-85	8.0	170	6	117	20.0	8.3	15.8	1.0	3.6	3.7	0.5	0.03

Watershed S1 suspended sediment concentration was lower three of the four months in 1984-85 compared to 1983-84. This would indicate that oak removal did not cause an increase in erosion. However, a comparison of estimated average annual sediment yield calculated as runoff times concentration for pre-cut and post-cut years indicates an increasing trend with harvesting (Table 5). Prior to oak removal, S1 and S2 produced an average yield of .2 and 3 short tons, respectively. After oak removal, production increased to .4 short tons on S1 and 24 short tons on S2; at the same time, the average rainfall and runoff decreased. Also on S2 during the two highest rainfall years, 1981-82 and 1982-83, sediment yield was an average 5 short tons compared to 47 short tons produced in post-cut 1985-86, an average rainfall year (Table 1). However, the intense storm activity in February of 1985-86 may be responsible for the high yield and not oak harvesting.

Table 5 Estimated Average Annual Sediment Yield for Pre (1980-81, 1981-82 & 1982-83) and Post (1984-85 & 1985-86) Harvest Years.

		Runoff		Sediment Yield	
	Rainfall	S1	S2	S1	S2
	---------- inches	----------		------- short tons -------	
Precut	36	14	20	.2	3
Postcut	26	9	14	4	24

Modeling Sediment Yield. The SAS PLOT procedure was used to obtain scatter diagrams of the data, along with SAS GLM to determine the regression equations which best describe the relationship between runoff and sediment yield. The data was found to be non-normally distributed particularly the sediment concentration (C_s), and log transformation of both C_s and the runoff (cfs) were taken to induce normality. This was necessary due to the wide variation in the range of C_s values for a given cfs value. A separate curve was fit to data for each year, for pre and post cut years, and by season.

Simple linear regressions fit the data best in most years, however, on S1 in 1980-81 and 1984-85 and on S2 for the last three years, third degree polynomials were chosen. for each year 1980-86, respectively, an r^2 = .56, .68, .32, .55, .33 and .44 was found for S2. The variability in C_s unexplained by cfs may be partly due to the error inherent in sampling during low flows. During low flows, the water sampled may be contaminated by disturbed stream bed material.

Conclusion

We have found that sediment and nutrient losses tend to be small for both watersheds. The careful removal of oaks, according to the methods prescribed by the field station, did not have an effect on either runoff or water quality.

However, we do not have sufficient data to come to any conclusions about the impact of vegetation removal on sediment yield. Additional years of data will be collected to determine, more conclusively, if type conversion has an effect on water quality. Studies of this kind are, of necessity, long term because of the highly variable precipitation and responses to precipitation. A very wet year would be useful to compare with the two above average rainfall years occurring before harvesting. Also, an average rainfall year of data is required to determine if the sediment yield increases due to oak removal or if the high yield in 1985-86 was only a one year phenomenon due to a period of very high rainfall intensity.

In order to extend data of the kind we have collected to other watersheds, it is necessary to relate the water flow and water quality information to basic hydrologic and erosion processes. We have collected all of the data necessary to test the applicability of the Modified Universal Soil Loss Equation for predicting single-storm sediment yield in the Sierra Foothills.

Two possible results may come from our modeling efforts. If we show that the MUSLE is useful, with a reasonable degree of accuracy, it will be a significant aid to watershed planners and managers who will be able to use it for predicting the effects of management options on water quality. If alternatively, we cannot show that the model is accurate, we may be able to improve or devise a model with our findings. In either case, the result will be beneficial to watershed managers concerned with water quality.

Monitoring continues to provide useful qualitative data on the effects of treatment while validation of the model can have far reaching implications if it is accurate on our watersheds.

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UNDERSTORY FORAGE PRODUCTION IN BLUE OAK WOODLANDS

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Summary

Preliminary guidelines for management of hardwood range published by UC Cooperative Extension in 1985 suggest that in areas with more than 20 inches of annual rainfall, tree cover of 50 percent or more suppresses the understory. This guideline has important implications for management of the oak canopy for enhancement of forage production. Previous work on this subject used different locations, different canopy cover, different tree species, and different stand types, leading to conflicting results and recommendations. In fall 1985 we established five study locations to examine the differences in composition and production between open grassland and the blue oak canopy. The sites were selected to be as uniform as possible, with approximately 50 percent blue oak canopy cover, a history of cattle grazing, and similar site potential other than rainfall. We compared canopy to open and differences due to location along an annual rainfall gradient from 35 to 90 cm/yr, measuring production and composition in fall, winter, and at spring peak for the 1985-6 season.

Grassland production was always greater in the grassland compared to canopy on sites with more than 80 cm rainfall, while only peak production was greater on a site with with 60 cm rainfall. Below 50 cm annual rainfall, production was never greater in the open grassland; one site had greater understory production in the fall. Along a rainfall gradient within the blue oak woodland with 50 percent canopy, suppression of understory production occurs above 50 cm rainfall. The canopy has no effect or an enhancement below 50 cm annual precipitation. Species composition differed more between open and canopy than between sites. The differences in composition were smallest where differences in productivity between open and canopy were smallest. Location combined with plant species composition offers potential as a useful guide to predict the effects of blue oak canopy removal or retention.

THE INTEGRATED HARDWOOD RANGE MANAGEMENT PROGRAM

Doug D. McCreary

WHY STUDY HARDWOODS?

Hardwoods grow on approximately 20 million acres in California (Bolsinger). To date, however, there has been little interest in studying or managing this resource. This is largely because hardwoods have relatively little commercial value. For instance there is currently only one oak sawmill in the state, and the only other commercial use for oaks is for firewood. Because of the great disparity in economic importance between hardwoods and softwoods, it is not surprising that forestry research in California has focused almost exclusively on conifers.

While most residents of the state have tended to take hardwoods for granted, a number of individuals and organizations have recently voiced concerns that the existence of some hardwood species -- especially oaks -- is threatened. They cite extensive harvesting for firewood, removal for commercial and residential development, and clearing for range improvement as factors that have taken a heavy toll on oaks. They also point to evidence that for several oak species, natural regeneration is not occurring at a sufficient rate to ensure the continuation of the stands (Bolsinger, Muick and Bartolome). Without young trees to replace those that are cut down or naturally die, the extensive ranges of oak woodland that grow throughout California could become depleted. Such a loss would not only alter the distinctive character of California's landscape, but also affect wildlife, since a great number of animal species live in oak-covered areas and rely on the trees for both food and shelter.

THE HARDWOODS PROGRAM

In response to these concerns, the University of California and the California Department of Forestry jointly agreed to support a research and education program aimed at the management, enhancement and protection of the State's hardwood range resources. The Integrated Hardwood Range Management Program is modeled after UC's highly regarded Integrated Pest Management Program. It has four main objectives: (1) the improvement of oak regeneration, (2) maintenance of wildlife habitat diversity, (3) the mitigation of unsound conversion of hardwood rangelands to intensive agriculture or residential development, and (4) the development of feasible alternative management strategies for hardwood range owners.

NATURAL RESOURCES SPECIALISTS

To accomplish these objectives, five natural resources specialists were hired by Cooperative Extension to study hardwoods and develop educational programs to promote wise and informed management by woodland owners. These specialists are located in five regions of the state, including one housed at the Sierra Foothill Range Field Station.

RESEARCH PROJECTS AT THE SIERRA STATION

In addition to establishing these specialist positions, the Hardwoods Program also began funding research projects, selected on a competitive basis, designed to fill in the most conspicuous gaps in our current knowledge and understanding about hardwoods. During the past year, twelve projects were funded, including two that have field plots at SFRFS. The first of these, by wildlife scientists at U.C. Berkeley (Morrison and Block), is examining the relationships between oak-woodland habitats and wildlife occurrence and use. A number of transects have been established along gradients encompassing a wide diversity of oak communities found at the Station. Periodic monitoring of sample points along these transects will help determine what vertebrate species are associated with, and use, different vegetation types.

A second study, by range scientists at U.C. Davis (Rice, Menke and Welker) is investigating how various factors influence the regeneration of blue oak seedlings. This project will focus on how grazing, and the associated changes in plant composition and soil properties, affect the ability of young blue oak seedlings to become established. It will also examine the influence of overstory canopy on seedling recruitment.

In addition to these projects, there are also several on-going studies at the Station investigating other hardwood-related questions including (1) the effects of oak removal on forage production; (2) the success of different stock types and fertilization regimes on white oak regeneration; (3) the relative importance of the environment vs. genetics in controlling bud burst and flowering date in black oak; (4) the ability of several eucalyptus and poplar species to produce biomass for firewood; and (5) the effects of brush piles, created from oak firewood harvesting residue, on wildlife abundance and habitat use. Another study, that is scheduled to begin in June, 1987 will examine the sprouting of blue oak stumps for different cutting dates and different stump heights.

It is hoped that this cooperative effort by the U.C. Agricultural Experiment Station, the California Department of Forestry and other public and private organizations will lead to an increased understanding of the biology of hardwoods and an appreciation of their importance to other natural resources. By also developing a effective educational programs to deliver this knowledge to woodland owners and managers, this Hardwoods Program will help ensure that the multiple values of California's hardwood resources will be preserved for future generations.

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EVALUATION OF HARDWOOD SPECIES FOR FUELWOOD

Janine Hasey, Richard Standiford, Roy Sachs, Mike Connor

Foothill and valley landowners are increasingly interested in growing trees as energy crops both commercially or for their own use. The potential markets for these trees are as firewood, biomass for co-generation plants, or as pulpwood chips for lumber companies.

One hardwood tree in particular, the genus Eucalyptus, has performed well in several trials throughout California. Eucalyptus are generally fast growing, tolerant of poor sites and produce energy values comparable to oak wood.

In March, 1984, a clonal and seedling plantation of selected Eucalyptus and poplar species was planted at the University of California Sierra Foothill Range Field Station at 575 feet elevation. The main objectives of this six year project are to evaluate survival and growth characteristics and to determine optimum harvest time of hardwood trees as energy crops grown under foothill conditions.

Eucalyptus species and clonesof Eucalyptus and poplar were planted in a randomized complete block design in a 6 foot x 6 foot spacing (1210 trees per acre). The provenance or seed source of the Eucalyptus species is very important in determining ultimate growth. The seed sources were carefully selected for desirable traits. Based on previous research conducted at the Sierra Field Station and elsewhere in California, the species, clones and provenance in this plot were chosen for their cold tolerance and/or fast growth.

Species or clone		Provenance
-Eucalyptus	globulus	Barnback, Australia
-E.	camaldulensis	Lake Albacutya, Australia
-E.c.	C-1 clone	Unknown
-E.c.	C-2 clone	Improved Spanish seed
-E.	viminalis	South coast, New South Wales, 200 ft. elevation, Australia
-E.	dalrympleana	Longitude unknown, latitude 35 S 800 ft. elevation, Australia
Poplar		Zappettini "Giacometti" clone

Height and diameter at breast height (DBH) measurements were taken in October 1985 and 1986 when the trees had grown for 19 months (tables 1 and 2) and 2½ years (tables 3 and 4).

The following tables report average diameter at breast height (DBH) and height of surviving trees.

TABLE 1. DBH in Inches	1985	
Eucalyptus globulus	2.45	A
E. camaldulensis	2.21	A
E. camaldulensis C-2 clone	2.16	A
Poplar clone	1.82	B
E. dalrympleana	1.80	B
E. viminalis	1.79	B
E. camaldulensis C-1 clone	1.65	B
LSD (.05)		

TABLE 2. Height in Feet	1985	
Eucalyptus globulus	25.6	A
E. c. C-2 clone	22.6	B
Poplar clone	20.4	BC
E. camaldulensis	19.5	CD
E. viminalis	17.9	DE
E. dalrympleana	17.6	DE
E. c. C-1 clone	15.8	E
LSD (.05)		

TABLE 3. DBH in Inches	1986	
Eucalyptus globulus	3.22	A
E. camaldulensis C-2 clone	3.14	AB
E. camaldulensis 'Lake Albacutya'	2.99	ABC
E. dalrympleana	2.92	ABCD
Poplar clone	2.84	BCD
E. viminalis	2.81	CD
E. camaldulensis C-1 clone	2.64	D
LSD (.05)		

TABLE 4. Height in Feet	1986	
E. globulus	36.53	A
E. c C-2 clone	34.50	A
Poplar clone	29.72	B
E. viminalis	27.35	BC
E. dalrympleana	27.06	BCD
E. camaldulensis	25.97	CD
E.c. C-1 clone	24.35	D
LSD (.05)		

Treatments followed by the same letter are not significantly different.

Survival rate by species:

E. globulus	94%
E.c. C-2 clone	100%
E. camaldulensis	100%
Poplar clone	100%
E. viminalis	83%
E. dalrympleana	97%
E.c. C-1 clone	100%

In October 1986, taper measurements were taken on a subsample of each species to develop volume relationships. This allows total per acre cubic foot yields to be compared for the various species. Table 5 lists the volume in mean cubic feet per acre and volume production in cords per acre of merchantable wood in a 2½ year period.

TABLE 5. Volume Production

	cu. ft./ individual tree	cu. ft./ acre	cords/acre/ 2½ years	
Eucalyptus globulus	0.89	1075	12.7	A
E.c. C-2 clone	0.86	1041	12.2	AB
E. dalrympleana	0.69	838	9.9	ABC
E. viminalis	0.64	778	9.2	BCD
E. camaldulensis	0.62	754	8.9	CD
Poplar clone	0.56	659	7.8	CD
E.c. C-1 clone	0.47	566	6.7	D

LSD (.05)

Wood properties will be sampled periodically in the future to determine moisture content and dry weight per unit volume. Final harvest volume will be taken once it has been determined that growth rate has reached its maximum.

Enemies of White Oak Regeneration in California[1]

Theodore E. Adams, Jr., Peter B. Sands, William H. Weitkamp, Neil K. McDougald, and James Bartolome[2]

Abstract: Blue oak (Quercus douglasii) and valley oak (Q. lobata) acorns and nursery stock (2-month-old and 1-year-old) were planted in six counties during the 1985-1986 growing season (October 1 to September 30), but each plant material was not planted at all sites. Results suggest weed competition was a major cause of poor emergence and survival of seedlings developing from field-planted acorns and survival of transplanted nursery stock. These problems were aggravated by use of a slow release fertilizer placed beneath acorns and transplants. Small mammals and insects were responsible for additional mortality at all locations.

In 1985-86, a series of artificial oak regenerations studies, using blue oak (Quercus douglasii) and valley oak (Q. lobata), was started in six counties: Yuba, Mendocino, Contra Costa, San Benito, Madera, and San Luis Obispo (fig. 1). Acorns planted directly in field plots and nursery transplants, 2-month-old and 1-year-old stock, were used, but each plant material was not planted at all sites. Acorns were planted in November and transplants in winter. Each site was as flat as the terrain permitted to minimize the influence of slope exposure. All work was conducted inside deer-proof exclosures and away from canopy effects on oak-grassland range supporting mature stands of the trees. These studies are supported by a 3-year grant from the Environmental License Plate Fund.

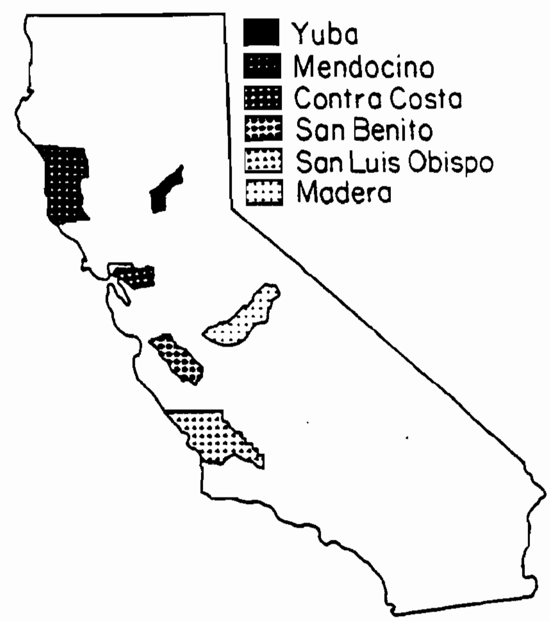

Figure 1--Counties in which regional artificial oak generation is being studied.

PROCEDURES

Acorns

Treatments used were: acorns planted with and without winter weed control, obtained with a systemic herbicide applied after planting but before emergence; and these treatments combined with and without fertilizer, slow release Osmocote® 18-6-12 (8-9 month release) buried beneath individual acorns. Treatments were organized in a randomized complete block design.

At one location, the Yuba County site, damage from grasshoppers became severe in June. To prevent complete loss, protection, in the form of hair nets used in the food processing industry, was applied to half the surviving plants, which were found only in fertilized and unfertilized treatments where herbicide was sprayed. This application created a split-plot design with respect to treatments with weed control.

Transplants

Winter planting of both age classes was accomplished after application of a systemic herbicide to reduce weed competition. Planting was done with and without Osmocote® buried beneath individual plants and with and without rodent protection, Foregon® rigid plastic protectors. These treatments were combined in a split-plot design with fertilizer treatment assigned to main plots

[1]Presented at the Symposium on Multiple-Use Management of California's Hardwood Resources, November 12-14, 1986, California Polytechnic State University, San Luis Obispo, California.

[2]Extension Wildlands Specialist and Staff Research Associate, respectively, University of California, Davis, California; Farm Advisors, University of California Cooperative Extension, San Luis Obispo and Madera, California, respectively; Associate Professor of Forestry, University of California, Berkeley, California.

and rodent protection assigned to subplots. Insect protection, hair nets, also was included at one location in July.

RESULTS

Oak Seedling Emergence

Adequate weed control in spring and summer was a problem in nearly all seeded plots treated with a systemic herbicide in winter. Winter weed control did not prevent spring emergence of weed competition in most sprayed plots. As a result, the effect of weed control on emergence could not always be measured. However, in Yuba County, the beneficial effect of weed control was easily seen (fig. 2).

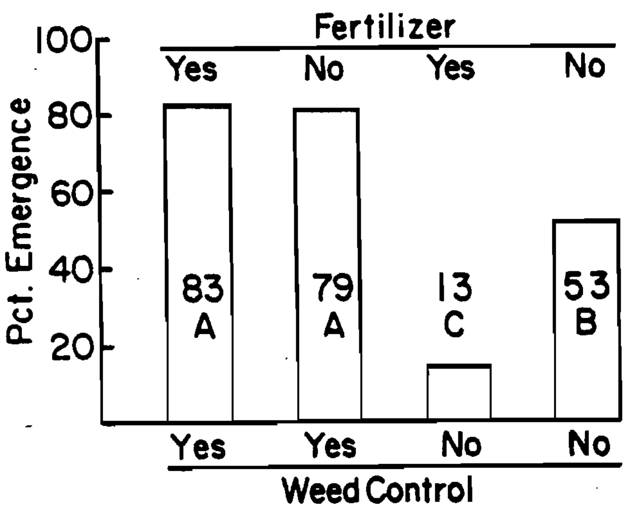

Figure 2--Percent emergence of blue oak seedlings in response to the combined effects of weed control and fertilizer (Yuba County).[3]

On the basis of seedling emergence, valley oak is a stronger competitor than blue oak. In San Benito County, where both were growing in the same plot, valley oak produced 7 times as many seedlings as blue oak.

Fertilizer aggravated the problem of competition by stimulating weeds and reducing oak seedling emergence (figs. 2 and 3). The effect was particularly evident where weed control was not used.

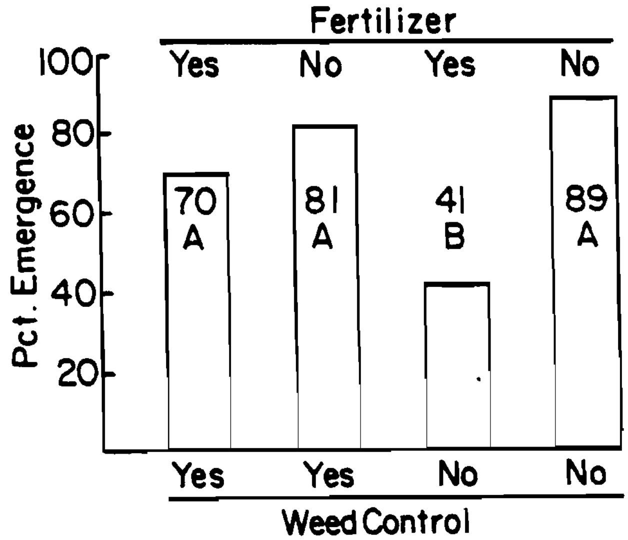

Figure 3--Percent emergence of valley oak seedlings in response to the combined effects of weed control and fertilizer (San Benito County).[3]

Small mammals were a problem at all sites. At the Madera County site, ground squirrels dug up all acorns, more than 5,000. Also, pocket gophers contributed an unmeasured amount to mortality of all seedings.

Oak Seedling Survival

Incomplete control of late spring and summer weeds in many sprayed plots masked the possible value of weed control on survival. However, in Yuba County, no blue oak seedlings survived beyond the middle of June without weed control. At another site, the presence of weeds, stimulated by fertilizer in unsprayed plots, reduced survival by half compared with plots both sprayed and fertilized (fig. 4).

Due to stimulated weed competition, fertilizer had a negative effect on survival at all sites. At three sites, survival was 2 to 10 times greater without fertilizer (figs. 4 and 5).

Grasshopper depredation was severe in Yuba County. Protection applied in June to plants in sprayed plots insured 10 times the survival compared with unprotected plants (fig. 6).

Oak Transplant Survival

Survival of transplants was adversely affected by fertilizer wherever used. For 2-month-old blue oak transplants, survival without fertilizer ranged from about 15 percent more to 6 times more than with fertilizer (fig. 7). Without fertilizer survival of 2-month-old valley oak ranged from 2.5 times more to nearly 30 times more (figs. 8 and 9). Where both age classes of valley oak were

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[3]Values with the same letter are not different ($P \leq 0.05$) by LSD Separation. Where necessary, the arcsine transformation was used in the analysis to insure homogeneity of variances.

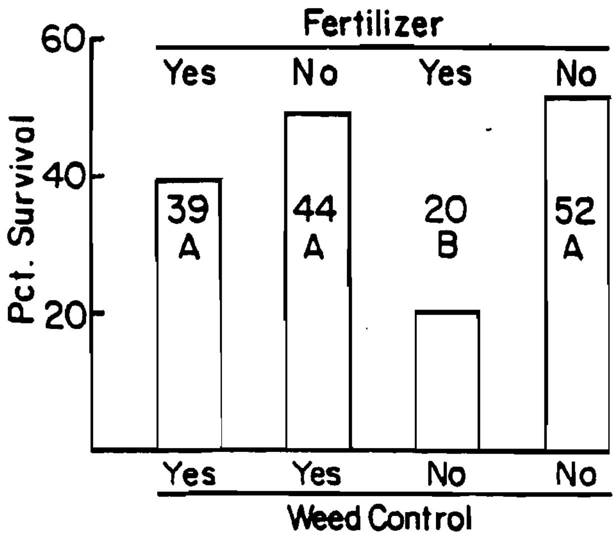

Figure 4--Survival of valley oak seedlings as a percent of emergence (74 pct. without fertilizer and 56 pct. with fertilizer[4]) in response to the combined effects of weed control and fertilizer (San Luis Obispo County).[3]

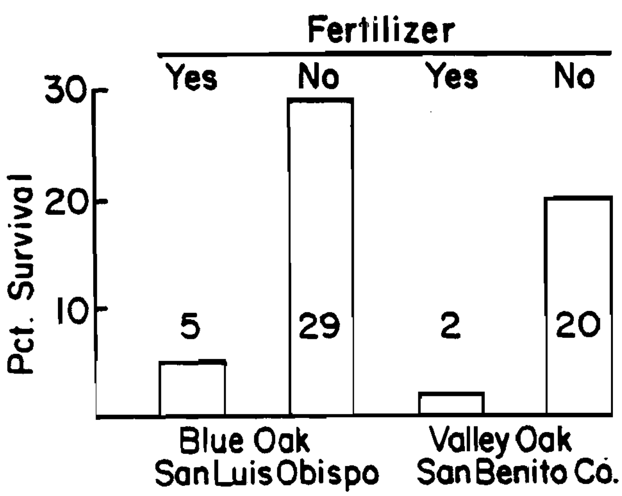

Figure 5--Survival of blue oak seedlings as a percent of emergence (65 pct. in San Luis Obispo County and 72 pct. in San Benito County) with and without fertilizer.[4]

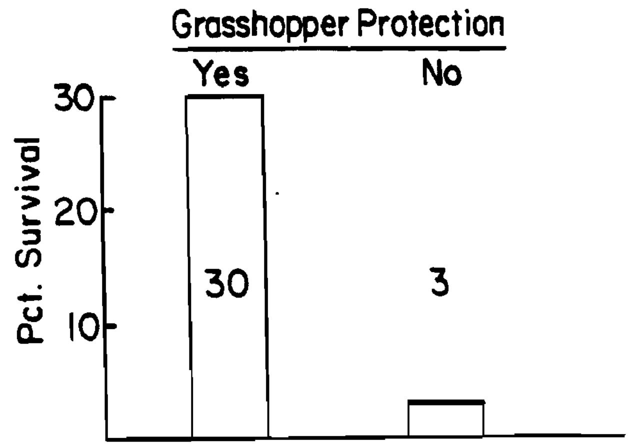

Figure 6--Survival of blue oak seedlings as a percent of emergence (81 pct.) with and without grass hopper protection in the weed control treatment (Yuba County).[4]

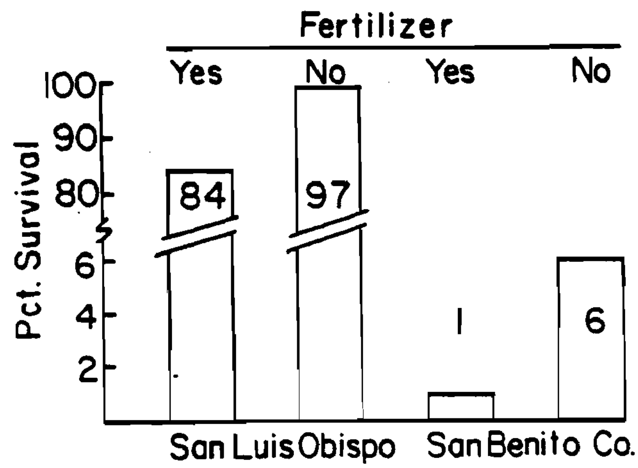

Figure 7--Percent survival of 2-month-old blue oak transplants with and without fertilizer.[4]

planted together and no difference in survival between the two existed, absence of fertilizer increased survival by nearly half (fig. 10).

Moisture stress from weed competition in spring and summer was a problem despite use of a systemic herbicide to control winter growth. Weed regrowth after planting and the competition for moisture it represented is assumed to have played a role in eliminating all blue oaks of both age classes in Mendocino County and Yuba County and all 1-year-old valley oak stock, the only plant material used in Contra Costa County.

Protection against small mammals proved valuable at nearly all sites. Survival with protection ranged from about one-third more to 13 times more than without protection (figs. 8 and 11). Problem animals included jackrabbits, cottontail rabbits, squirrels, and pocket gophers. However, the Foregon® rigid plastic protectors provided no

[4]Values different at $P \leq 0.05$. Where necessary, the arcsine transformation was used in the analysis to insure homogeneity of variances.

protection against pocket gophers that attacked seedlings from below the soil surface.

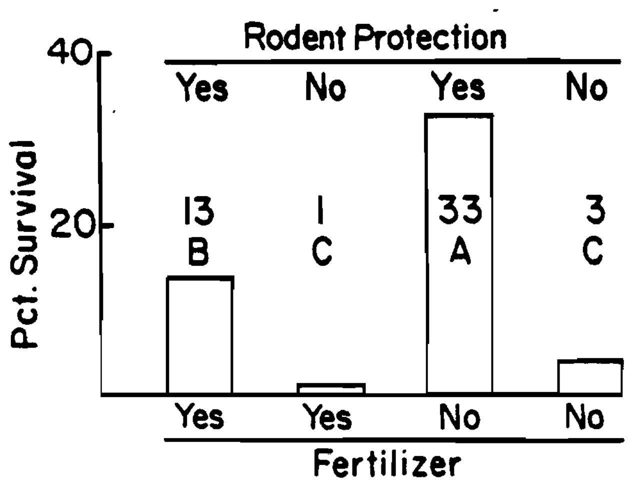

Figure 8--Percent survival of 2-month-old valley oak transplants in response to the combined effects of rodent protection and fertilizer (San Benito County).[3]

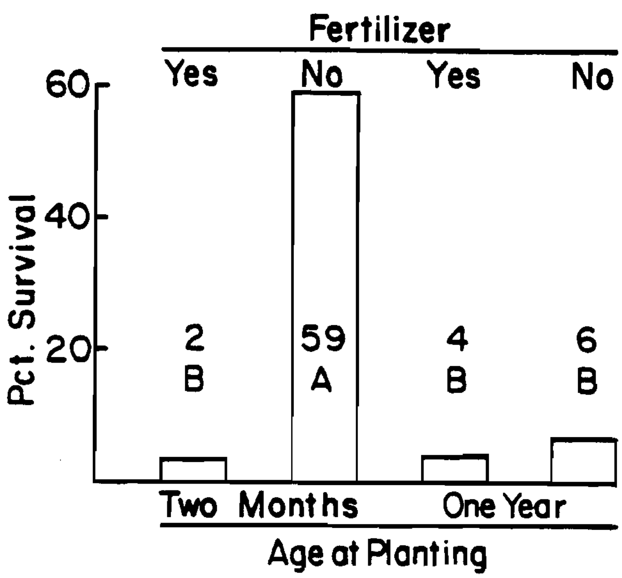

Figure 9--Percent survival of valley oak transplants in response to the combined effects of age, class, and fertilizer (San Luis Obispo County).[3]

Protection from grasshoppers was necessary at the Mendocino County site. Here, protection of valley oak transplants increased survival by more than one half (fig. 10).

The effect of age class on survival was most obvious at the San Luis Obispo County site. Valley oaks of both age classes were planted together. Survival of unfertilized 2-month-old stock was nearly 12 times more than 1-year-old stock (fig. 9).

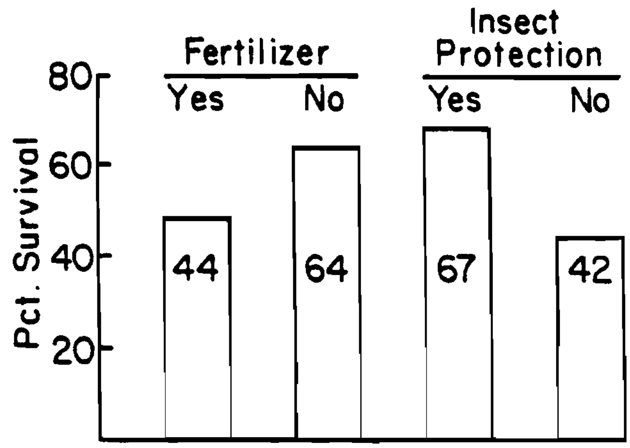

Figure 10--Percent survival of valley oak transplants with and without fertilizer; and with and without insect protection (Mendocino County).[4]

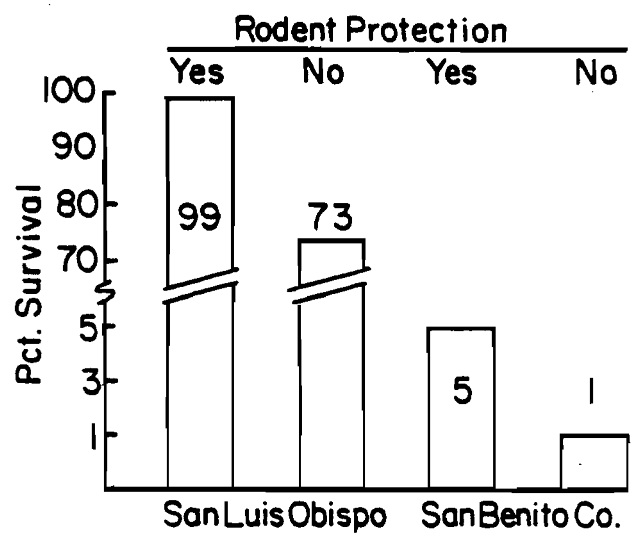

Figure 11--Percent survival of 2-month old blue oak transplants with and without rodent protection.[4]

SUMMARY

Oak regeneration from acorns and nursery transplants faces many obstacles. Included are competition from spring and summer weeds, small mammals, and insects. Competition from weeds (moisture stress) may be the most important factor, but small mammals and insects can be major local problems. Weed control in late spring and summer will not only reduce competition, but will also discourage pocket gophers, a universal problem, by removing an attractive food source. In some areas, regeneration from seeded acorns and nursery transplants is unlikely without protection from all described enemies.

For field transplants, 2-month-old nursery stock appears superior to 1-year-old stock. Ignoring survival, the younger material is cheaper to grow and easier to transport and plant.