Blue and Valley Oak Seedling Establishment on California's Hardwood Rangelands[1]

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Abstract: Factors contributing to poor establishment of blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) in California oak-grassland savannas were studied in a series of acorn seeding experiments initiated in 1985. Exclusion of large herbivores permitted examination of herbaceous interference and small mammal and insect depredation. Herbaceous interference was the most important factor. Average emergence in all blue oak seedings with and without herb control was 45 percent and 29 percent, respectively. The respective values for all valley oak seedings were 60 percent and 46 percent. Average first year survival, expressed as a percentage of acorns planted, was significantly improved by elimination of herbs in both blue oak (30 percent vs. 11 percent) and valley oak (45 percent vs. 25 percent) seedings. Limited data suggests the differential in survival is maintained over time as overall survival declines. With few exceptions, the addition of screen protection to discourage predation significantly enhanced survival and growth. Shade provided by window screen cages is suspected of making an unmeasured positive contribution. Interaction between herbaceous control and protection appears to develop with time.

In the most recent and comprehensive inventory of California's hardwoods, Bolsinger (1988) reports that livestock graze the majority of nearly 3 million hectares of noncommercial woodland where oaks (*Quercus* spp.) are the dominant trees and blue oak (*Q. douglasii*), occupying about 1.2 million hectares, is the dominant hardwood type. The author also states that recruitment in blue oak stands is relatively sparse and almost nonexistent in valley oak (*Q. lobata*) stands. Results of a germination study in Monterey County suggest that unsuccessful blue and valley oak recruitment results from mortality in seedling and sapling stages rather than from inadequate germination and seeding emergence (Griffin 1971). In a later study of regeneration based on analysis of tree rings, McClaran (1985) suggests that the transition from a seedling to sapling and tree stages is more critical in limiting regeneration than acorn germination and early seedling survival.

Clearing of woodlands in rangeland improvement projects and poor natural regeneration were two of 19 concerns identified by the Hardwood Task Force of the California Board of Forestry in its December 1983 draft report (Passof and Bartolome 1985). Development of artificial restocking techniques and identification and quantification of problems associated with these techniques are needed to address the concerns raised and preserve management options in oak woodlands.

This paper examines the potential of artificially sown acorns for establishment of oak in oak woodlands of California. Specifically, we evaluated the impacts of herbaceous interference and small mammal and insect herbivory on emergence, survival, and growth of seedlings. Included is an evaluation of selected techniques for reducing negative impacts.

STUDY SITES

Over a period of 5 years, blue and valley oak acorns were directly seeded in field plots in six counties lying between latitudes 35°15' and 39°15'N (fig. 1). These oak woodland sites in California's Mediterranean-like climate have understories

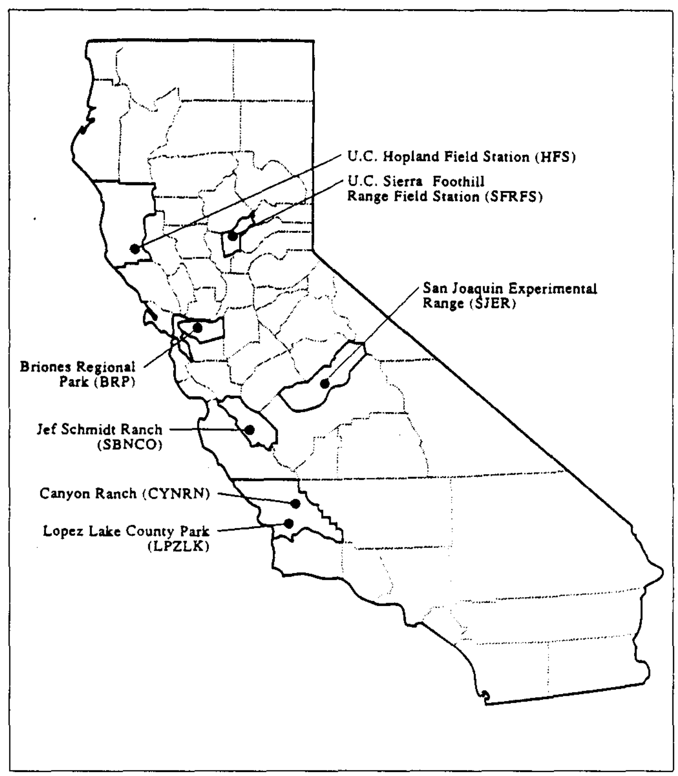

Figure 1—Location of 7 oak-grassland study sites.

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dominated by annual grasses. Throughout the study area, annuals continue to grow until all available soil water is exhausted. A discussion of the ecology and composition of California annual grasslands is presented by Heady (1977). Menke (1989) describes the influence of biomass management (grazing) on productivity and composition.

San Luis Obispo County was the most southerly site for acorn plantings of the two oak species. Valley oak was planted at Lopez Lake County Park (LPZLK) and blue oak on the Canyon Ranch (CYNRN). The San Benito County plantings of both oaks were made on the Jef Schmidt Ranch (SBNCO). In Madera County, blue oak was planted on the U.S. Forest Service San Joaquin Experimental Range (SJER). In western Contra Costa County, the two oaks were planted in Briones Regional Park (BRP), part of the East Bay Regional Park District. In Mendocino County, the two oaks were established at the University of California Hopland Field Station (HFS). In Yuba County, blue oak was planted on the University of California Sierra Foothill Range Field Station (SFRFS). Elevation, rainfall, and soil characteristics (table 1) represent conditions typical of those occurring in natural stands of the oaks found in the Coast Ranges, interior coastal ranges of the San Joaquin Valley, and western foothills of the Sierra Nevada in the Sacramento and San Joaquin Valleys.

METHODS

Acorns were collected from trees in late summer through early fall, dusted with captan and placed in 0.08 mm clear plastic bags with material at the bottom to absorb excess moisture from respiration. The acorns were then placed in cold storage (4°C) until planting. Storage between 1°-4°C is recommended by Korstian (1927) and Harrington (1972) to retard germination without a reduction in emergence potential.

Plantings of blue and valley oak acorns were made in late fall each year (November-December) from 1985-1989. Not all locations were included each year because annual acorn production was irregular and sometimes inadequate for establishment of plantings.

Acorns were sown in open areas away from canopy effects and on terrain as flat as possible to reduce effects of slope exposure and inclination. All work was conducted within deer-proof enclosures to exclude browsing of seedlings by deer and livestock, an acknowledged problem (Franco 1976, Longhurst and others 1979, Menke and Fry 1980) and to prevent depredations by feral pigs (*Sus scrofa* Linnaeus).

At each site, treatments were the factorial set of two levels of herbaceous plants (none and the naturally occurring vegetation) and two levels of protection against small mammal and insect damage (screens and no screens). The experimental design was a randomized complete block with the two levels of herbaceous plant control as main plots and protection applied as a split on main plots.

Main plot treatment each consisted of 100 acorns planted in four rows of 25 each with 30 cm between acorns and rows. Planting depth was 5 cm, a depth suggested for use in controlled environments (Lobel and George 1983) and one considered a minimum to discourage disturbance by mice (Griffin 1971). In other research, this depth has been found to be a good compromise between improved protection from predation and reduced emergence that occurs from planting at a greater depth (Tietje and others 1991).

During planting, acorns with obvious insect damage, usually consisting of exit holes created by larvae of the filbert weevil (*Curculio occidentis* Casey) and filbertworm (*Melissopus latiferreanus* Walsingham), were discarded. Acorns that had

Table 1—Physical parameters at locations included in blue and valley oak seeding studies.

			Soils		
Location	Elevation (m)	Avg. Annual Precip (cm)	Depth (cm)	Estimated AWC[1] (cm cm^{-1})	Series[2] and Surface Texture
			Blue Oak		
BRP	188	48	86	0.15-0.18	Los Osos clay loam
CYNRN	545	28	155	0.14-0.17	Ayar clay loam
HFS	273	94	183	0.14-0.17	Hellman loam
SBNCO	394	36	61	0.10-0.14	Santa Lucia shaly loam
SFRFS	182	72	53	0.11-0.16	Argonaut gravelly loam
SJER	333	48	74	0.09-0.12	Ahwahnee sandy loam
			Valley Oak		
BRP	124	48	193	0.16-0.18	Botella clay loam
HFS	273	94	152	0.14-0.17	Yorkville loam
LPZLK	158	51	183	0.10-0.15	Elder sandy loam
SBNCO	394	36	61	0.10-0.14	Santa Lucia shaly loam

[1]AWC = Available Waterholding Capacity
[2] All are upland soils except Botella and Elder which are alluvial.

germinated in storage were distributed among treatments and replicates to insure uniformity of potential emergence.

During the study, two blue oak seedings had to be planted twice because of depredation. At CYNRN in 1985, feral pigs dug up many acorns before fencing was erected. In the second instance at SFRFS in 1987, deer mice (*Peromyscus maniculatus* Wagner) were the suspected problem. This assumption is based on live trap records at the site.

Measurement of emergence was confounded by small mammal depredations. Some acorns were destroyed early at all locations, both before and after emergence. One seeding at SJER was destroyed in 1985-86 and could not be reseeded. The high population of ground squirrels (*Spermophilus beecheyi* Richardson) present at the time suggests this rodent was responsible. Subsequent seedings at SJER were made after the population was reduced, but control at this site was maintained throughout the study.

Pocket gophers (*Thomomys bottae* Eydoux & Gervais) were common at all sites, and control was practiced where populations were a significant threat. However, no level of control was adequate to prevent losses to this rodent. These depredations may have been encouraged by the geometric planting pattern and relatively close spacing of acorns. In addition, we noted that control of herbaceous plants discouraged depredation.

Emergents in each main plot were randomly split into two groups, protected and unprotected, with protection provided by window screen cages (closed cylinders 15 cm in diameter and approximately 40 cm high) or Foregon (formerly Vexar) 14-strand rigid plastic seedling protectors (screens) 5 cm in diameter and 30 cm high. The large mesh plastic screens were substituted for window screen cages in new plantings when the threat from grasshoppers (*Melanoplus devastator* Scudder) was minimal. As a consequence, the efficacy of this less expensive protection was evaluated in six seedings, two blue oak seedings each at CYNRN and SJER (1987 and 1988) and two valley oak seedings at LPZLK (1987 and 1988). At CYNRN and LPZLK, black tailed jackrabbits (*Lepus californicus* Gray) and rabbits (*Sylvilagus* spp.) are the suspected major predators, and ground squirrels are a threat at SJER. Protection was applied beginning in Spring 1987 to all one-year seedlings and new emergents.

Following 1986 emergence in the 1985 SFRFS seeding, hairnets used in the food processing industry were applied to seedlings in each treatment to protect against defoliation by grasshoppers. In subsequent seasons, window screen cages were used as described.

During the 1985-86 growing season, glyphosate, a systemic herbicide, was applied after planting to control herbaceous growth until oak seedling emergence. After emergence, herbs were hoed. In subsequent seasons, initial herb control in new seedings was obtained using both glyphosate and a soil active herbicide, atrazine, to eliminate existing herbaceous growth and most such growth that might appear after application. The combination was used to reduce labor. In established plantings, two soil active materials, atrazine and oxyfluorfen, were applied annually during winter dormancy for more effective control of herbaceous growth. Potential for damage to emerging oak seedlings discouraged use of the latter chemical during the season of planting.

In one blue and one valley oak seeding, each established in 1985 (CYNRN and LPZLK), herbaceous plant interference was eliminated in all treatments after the first season. This was necessary to provide access. A third seeding at CYNRN in 1986 was established only with control of herbaceous plants.

Observations evaluated by analysis of variance (ANOVA) included emergence, survival measured in the spring of each growing season, and height of plants each fall. When measuring height, the longest stem was used if branching occurred. Unless otherwise noted, significant differences are reported at the 95 percent level of confidence.

Since data were collected over several time intervals, time was a third factor in survival and was considered a second split (Steel and Tome 1960). When there was a significant time interaction, ANOVAs for each time interval were used to assess the treatment effects. This was done to insure a conservative interpretation of data.

When necessary for the ANOVA, raw data were transformed to maintain homogeneity of variances. The results presented are treatment averages for the original measurements.

RESULTS AND DISCUSSION

Emergence

Overall emergence of 14 blue and 10 valley oak seedings was improved through herb control (table 2). Average emergence of blue oak with control was 45 percent. Without control, it was 29 percent. The values for valley oak were 60 percent and 46 percent, respectively.

Effect of Herb Interference on Survival

Average first-year seedling survival of both oak species, expressed as a percent of acorns planted, was significantly greater without herbaceous interference. In 11 blue oak plantings, survival was 33 percent of acorns planted without herbs while 11 percent survived in the control. Survival in eight valley oak seedings with and without herb control was 45 percent and 25 percent, respectively. These significant differences occurred despite some variability among plantings (table 3). SBNCO was not included because herbs could not be controlled, and no survival was recorded in either treatment.

Information on survival over time is limited, but figure 2 shows average survival of 3-year-old blue oak seedlings growing with and without herbs in three plantings. Herb interference clearly has a negative impact on seedling survival. Differences recorded each spring were highly significant ($P \leq 0.01$) and there was a highly significant ($P \leq 0.01$) interaction between treatment

Table 2—*Emergence (percent) with and without herbaceous plant control in 14 blue oak and 10 valley oak seedings and the associated precipitation patterns.*

				Emergence (pct.)			
				Blue Oak		Valley Oak	
Location	Planting Season	Seasonal Precip (cm)	Percent Avg Annual Precip	No Herbs	Herbs	No Herbs	Herbs
CYNRN	1985-86	33	118	72a[1]	75a	—	—
	1987-88	27	96	64b	41a	—	—
	1988-89	15	54	71b	15a	—	—
SBNCO	1985-86	45	125	15b	4a	81a	88a
			65	20b	4a	—	—
SJER	1987-88	31					
	1988-89	33	69	59b	41a	—	—
BRP	1987-88	37	77	—	—	72b	15a
	1988-89	35	73	25b	la	84a	87a
	1989-90	37	78	50a	38a	18a	11a
LPZLK	1985-86	63	124	—	—	69a	59a
	1987-88	40	78	—	—	56b	34a
	1988-89	43	84	—	—	55b	30a
SFRFS	1985-86	86	119	78b	53a	—	—
	1986-87	48	67	43a	31a	—	—
	1987-88	54	75	35a	40a	—	—
HFS	1986-87	62	66	60b	41a	32a	26a
	1987-88	73	78	12b	0a	86a	75a
	1988-89	68	72	29b	18a	44a	35a
MEAN				45b	29a	60b	46a

[1]For each seeding and each species, values in rows not followed by the same letter are significantly different ($P \leq 0.05$).

and time. After 3 seasons, control of herbaceous plant interference resulted in survival of 40 percent more seedlings.

Effect of Screen Protection on Blue Oak Survival

The addition of screen protection after emergence to blue oak seedlings produced mixed results the first year. In two seedings (SFRFS 1987 and SJER 1988), screens had no effect on first year survival, possibly due to the episodic nature of some depredation. Average survival with and without protection was 26 percent. Seedling survival in three seedings (CYNRN 1987, HFS 1986 and 1988) was significantly enhanced with screen protection. Average survival with screens at the three locations was 33 percent of acorns planted compared to 26 percent without screens.

Limited information on survival over 3 seasons from four plantings shows that blue oak seedlings survive in higher numbers with screen protection when growing with herb control (fig. 3). The value of protection was apparent at the end of the first season and was highly significant ($P \leq 0.01$) through the 3rd season with a highly significant ($P \leq 0.01$) interaction between treatment and time.

Screen protection and herb control in three seedings (CYNRN 1987, HFS 1986, and SFRFS 1987) were compared over 2 seasons (fig. 4). Interaction between herbs and screens was recorded at the beginning of the 3rd season. Application of

Table 3— *Survival (percent of acorns sown) in 11 blue oak and 8 valley oak seedings after 1 season with and without herbs.*

		Survival (pct.)	
Location	Seeding	Herbs	No Herbs
		Blue Oak	
CYNRN	1985	23a[1]	33a
	1987	21a	36a
	1988	<1a	61b
BRP	1988	0a	18b
HFS	1986	22a	55b
	1988	7a	16b
SFRFS	1985	18a	47b
	1986	7a	25b
	1987	35a	33a
SJER	1987	0a	4b
	1988	2a	35b
MEAN		11a	33b
		Valley Oak	
BRP	1987	14a	62b
	1988	70a	71a
HFS	1986	3a	11b
	1987	38a	69b
	1988	7a	30b
LPZLK	1985	34a	39a
	1987	18a	42b
	1988	13a	34b
MEAN		25a	45b

[1]For each seeding, values not followed by the same letter are significantly different ($P < 0.05$).

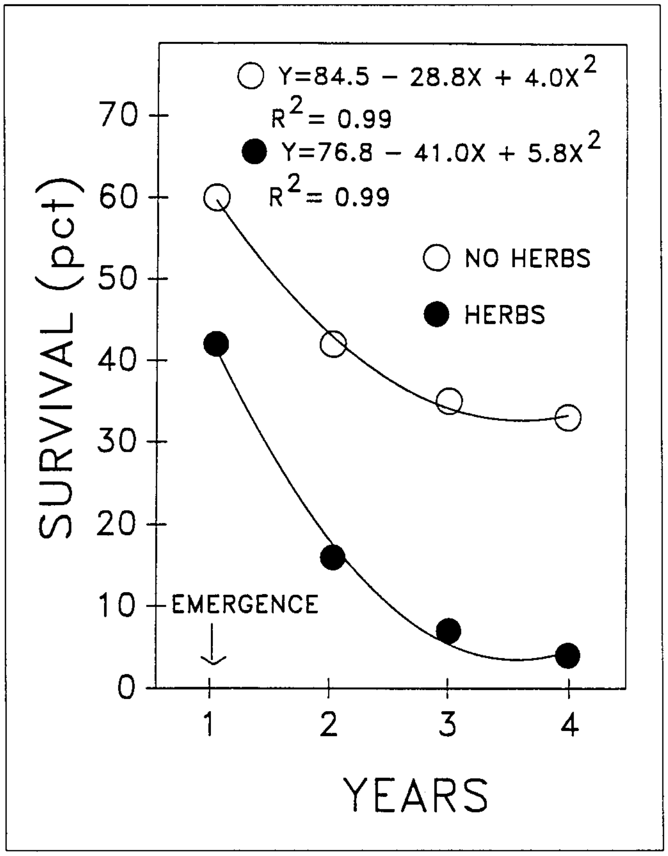

Figure 2—Three-season survival (percent of acorns sown) of blue oak combined over 3 seedings (HFS 1986, SFRFS 1985 and 1986) for plants growing with and without herbs. Observations made in spring after bud break. Difference in survival is highly significant ($P \leq 0.01$), and the progressive differential represents a highly significant ($P \leq 0.01$) linear interaction between treatment and time.

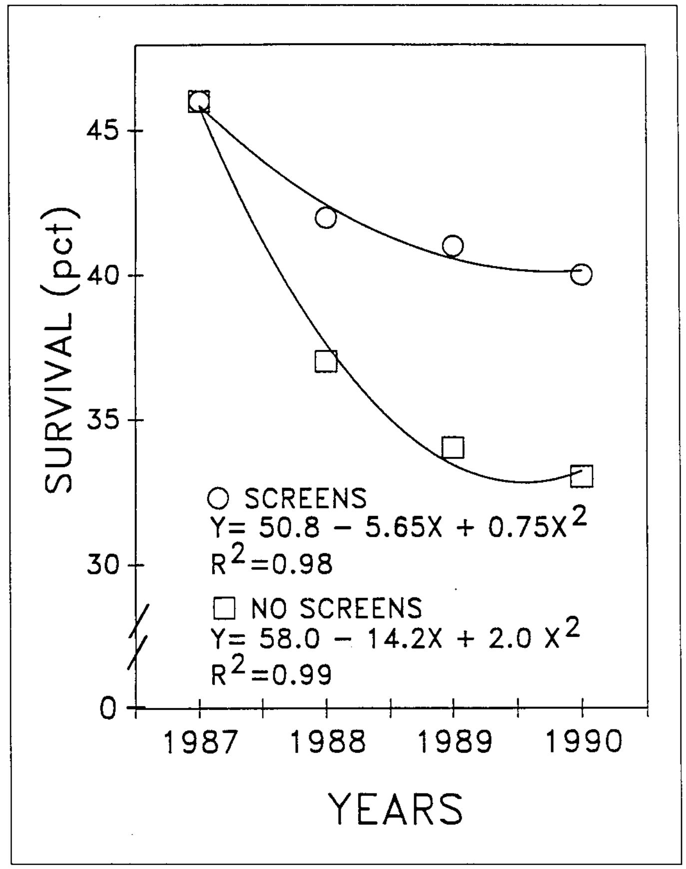

Figure 3—Three-season survival (percent of acorns sown) of blue oak combined over 4 seedings (CYNRN 1985 and 1986, HFS 1986, and SFRFS 1985) for plants growing without herbs and with and without screen protection. Observations made in spring after bud break. Difference in survival is highly significant ($P \leq 0.01$), and the progressive differential represents a highly significant ($P \leq 0.01$) linear interaction between treatment and time.

screens to seedlings growing with herbs nearly doubled survival. Screens increased survival only one-sixth where herbs were excluded.

Shade, as provided by window screen cages protecting blue oak in two seedings above, may have contributed to the large difference in survival between levels of protection where herbs were uncontrolled. Only 46 percent of incident sunlight is transmitted through window screen cages (measured in $\mu E/m^2/s$ by a quantum sensor). As a result, the environment beneath screens may provide an element of protection against excessive transpiration. That blue oak seedlings are tolerant of reduced sunlight beneath the screen cages is supported by data from other research in which the measured amount of transmitted sunlight did not significantly reduce net carbon gain (Kevin Rice, pers. comm.).

Effect of Screen Protection on Valley Oak Survival

The effect of screen protection on valley oak seedling survival the first season also varied by site. At BRP in 1988, survival was not influenced by window screen cages. Average survival with and without screens was 40 percent. However, use of screens in three seedings at HFS in 1987, 1988 and 1989 did produce significantly higher survival. On average, survival of protected and unprotected seedlings was 42 percent and 26 percent, respectively. Again, no interaction with level of herb control was detected.

In the 1987 and 1988 seedings at LPZLK, a significant difference in first year survival with and without screens (Foregon rigid plastic protectors) was recorded in both seedings, but in this case, survival without screens was greater. Without screens, average survival was 27 percent of acorns seeded compared with 22 percent for protected seedlings. Since most loss at this location occurred from gophers (88 percent in the 1988 seeding), the difference may have been due to their ability to identify and select protected plants.

Levels of both screen protection and herb control in 3 seedings were compared over 2 growing seasons (fig. 4). As with blue oak, interaction between levels of herbs and screens was recorded at the beginning of the third season. After 2 seasons, screens nearly doubled survival where herbs were excluded, but for the same period, survival of protected seedlings growing with herbs was three times that of unprotected seedlings. The greater difference in survival where herbs were

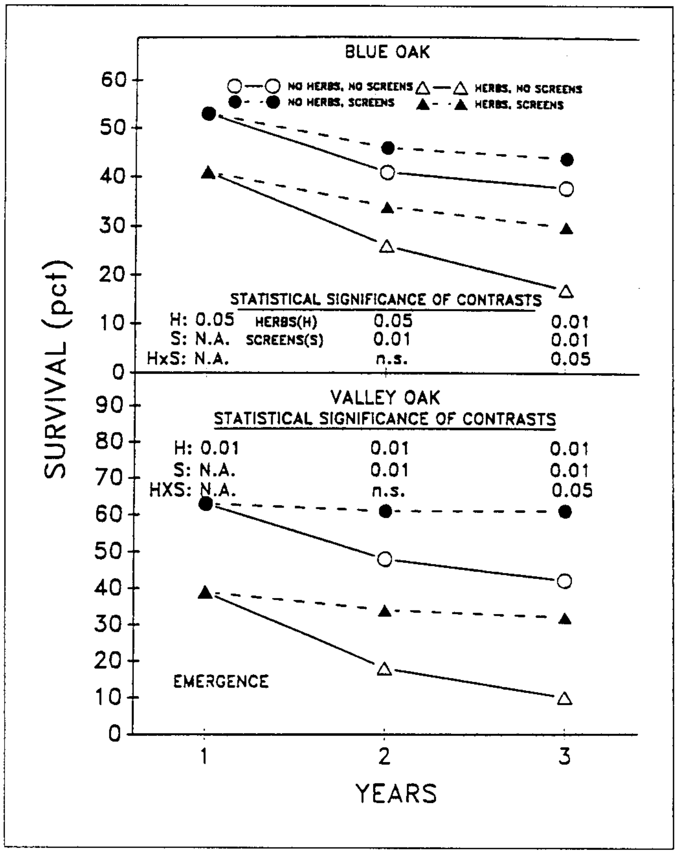

Figure 4—Two-season survival of blue oak combined over 3 seedings (CYNRN 1987, HFS 1986, and SFRFS 1987) and valley oak combined over 3 seedings (BRP 1987 and HFS 1986 and 1987) for all treatment combinations. Observations made in spring after bud break.

uncontrolled repeats the performance observed in blue oak seedings.

Effect of Screen Protection on Growth

Average height of 2-year blue and valley oak seedlings in 3 seedings was compared over all treatment combinations (table 4). The addition of screens in blue oak seedings more than doubled seedling height under the 2 levels of herb control at CYNRN, HFS and SFRFS. This response strongly suggests an interaction between screens and herbs.

The response of valley oak at HFS (two seedings) and LPZLK was equally as dramatic but not consistent between levels of herb control. Screens doubled seedling height where herbs were absent but increased height more than five times where herbs were present.

CONCLUSIONS

Control of herbs appears essential to achieve adequate emergence and first-year survival of blue and valley oak seedlings. Limited data on long-term survival suggests seedling mortality over time is reduced by herb control.

Screens protected seedlings against insects and small mammals and significantly improved survival and growth of both oaks at most locations. Window screen cages provided the best protection against grasshoppers, the principal insect herbivore on seedlings. Screens are recommended for all plantings.

Window screen cages not only protect seedlings from predation but modify the seedling microenvironment. They provide shade, the effects of which we could not separate from protection.

Other predators also appear to be affected by control of herbs (Wright 1985). The elimination of herbs around seedlings seemed to discourage pocket gopher predation. Control of this rodent is recommended in all plantings.

Predation in our studies may have been affected by concentrated planting patterns and characteristics of the exclosures.

We suspect the negative effects of herbaceous interference and predation can be modified by using livestock for phytomass control in carefully managed systems that would limit damage to oak seedlings. Such systems will reduce herbaceous cover and may effectively modify habitat, thus reducing potential predation. Such a strategy needs evaluation.

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Table 4—Average fall height of 2 year-old blue and valley oak each in 3 seedings (blue oak: CYNRN 1987, HFS 1986, and SFRFS 1987; valley oak: HFS 1986, HFS 1987, and LPZLK 1987) growing with and without both herbs and screens.

	Fall Ht. (cm)			
Species	Herbs and No Screens	Herbs and Screens	No Herbs and No Screens	No Herbs and Screens
Blue Oak	4.1a[1]	9.9b	10.1b	20.7c
Valley Oak	2.4a	13.5bc	10.1ab	21.0c

[1]Treatment values for each species not followed by the same letter are significantly different ($P \leq 0.05$). Those for blue oak represent an interaction (Herbs X Screens).

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