# Effect of Acorn Planting Depth on Depredation, Emergence, and Survival of Valley and Blue Oak[1]

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**Abstract**: During 1989 in east-central San Luis Obispo County, California, we studied the relationship of valley oak (*Quercus lobata*) and blue oak (*Q. douglasii*) acorn planting depth and number of acorns per planting site to acorn depredation, seedling emergence, survival, and height. Acorns were planted at three depths (1.3, 5.1, and 10.2 cm) at each of 960 planting sites with one or three acorns per site. Animal depredation of acorns was significantly ($P < 0.05$) greater for valley oak and seedling emergence and survival were significantly higher for blue oak. Depredation of valley oak acorns decreased significantly with deeper planting; depredation of blue oak acorns was significantly greater at the most shallow planting depth than at the two deeper depths where it was about the same. Although between-depth differences were not significant ($P > 0.05$), seedling emergence and survival of valley oak seedlings at the two deepest planting depths were better and almost identical. Conversely, blue oak seedling emergence and survival were significantly better at the two most shallow planting depths, and there was a strong, but insignificant, trend toward the best blue oak emergence and survival at the 5.1-cm depth. Regardless of planting depth, planting several acorns per planting site significantly decreased depredation and increased seedling emergence and survival for both oaks, and height for valley oak. Study results indicate that under the environmental conditions at the study site, the 5.1 cm (2 in) planting depth provided the best balance between lesser acorn depredation and greater seedling emergence and survival for blue oak; the 5.1 cm and 10.3 cm (4 in) depths provided the best balance for valley oak.

Poor natural regeneration of several of California's native oaks (*Quercus* spp.) has increasingly been recognized. Blue and valley oak are not regenerating sufficiently to maintain current stand densities. Factors that contribute to the regeneration problem include conversions of oak woodlands to urban and agriculture lands, increased fuelwood cutting, and competition from introduced Mediterranean annual grasses.

Artificial regeneration is an important option available for replacement of lost oaks. Although successful oak regeneration techniques have been developed (Griffin 1971; Russell 1971; Wright and others 1985; Johnson and Krinard 1985; Johnson and others 1986; Vande Linde 1987; McCreary 1989), animal depredation of direct-planted acorns is a common problem. Studies have examined several methods to reduce animal depredation. Johnson and Krinard (1985) concluded that a large-sized clearing around the planting site minimized animal damage. Russell (1971) believes that effective repellents would be a cost-efficient animal deterrent which needs to be developed. Cages surrounding planting sites keep animals out (Adams and others 1987), but are also expensive and take time to install.

Acorns planted at or just under the soil surface are more likely to be depredated than acorns planted at deeper depths (Russell 1971; Griffin 1971; Johnson and Krinard 1985; Borchert and others 1989). Optimal planting depth, however, has not been determined, at least not for California oaks. This paper reports on the response, in terms of animal depredation, seedling emergence, survival, and growth to valley and blue oak acorn planting depth and number of acorns planted per planting site.

## STUDY AREA

The study site was established on the Santa Margarita Ranch in east-central San Luis Obispo County about 23 km northeast of San Luis Obispo (fig. 1). The climate of the area is Mediterranean, characterized by warm, dry summers and cool, wet winters. Average monthly temperatures range from 8° C in January to 23° C in July. Average annual rainfall totals about 53 cm. Typically, no rain falls during May to October.

Topography of the area is gently rolling to hilly. Residual soils, formed in place on sedimentary or secondary rocks, predominate. The dominant vegetation community is foothill oak woodland (Barbour and Major 1988). Dominant tree species in the oak woodlands include blue and scrub oak (*Quercus dumosa*) on xeric sites and coast live oak (*Q. agrifolia*) and valley oak on the more mesic sites. Gray pine (*Pinus sabiniana*) is frequently interspersed with the oaks. A variety of brush, forbs, and annual grasses occupy the oak woodland floors and grassy openings.

Since European settlement of coastal central California, the predominant land use of the Santa Margarita Ranch has been livestock production. Currently, the ranch is stocked moderately with cattle. All data were collected on the ranch during January to October 1989 within a 1.8-m tall welded-wire fence exclosure constructed around 0.6 ha of grazed pastureland. Forbs, predominantly filaree (*Erodium* spp.) and annual grasses covered the exclosure; no trees or brush occurred within the exclosure.

[1]Presented at the Symposium on Oak Woodlands and Hardwood Rangeland Management, October 31 1990-November 2, 1990, Davis, Calif.

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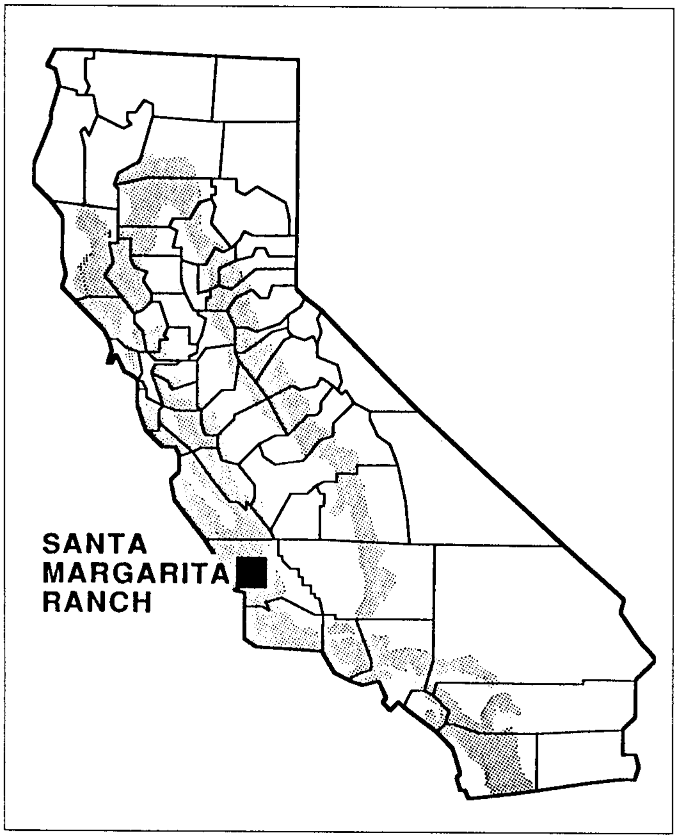


**Figure 1**—Location of the Santa Margarita Ranch in west-central San Luis Obispo County, California.

# METHODS

## Acorn Collection and Storage

In October 1988, valley and blue oak acorns were collected from trees on the Santa Margarita Ranch. The fungicide Captan was applied to the valley oak acorns, but not to the blue oak. All acorns were then refrigerated at 2° C until planting.

## Site Preparation

In January 1989 in the 0.6-ha exclosure, 960 planting sites were laid out in a 2.4- by 2.4-m (8- by 8-foot) grid divided into four replicates of 240 planting sites each (randomized complete block design). The large distance between planting sites was used in an attempt to reduce the likelihood of a potential acorn depredator which, if it happened to find one planting site, would be more likely to find another. Twelve treatments were assigned randomly to each replication using the following variables: blue oak or valley oak; planting depths of 1.3, 5.1, or 10.2 cm (0.5, 2.0, or 4.0 in, respectively); and one or three seeds per planting site.

Each planting site was marked permanently with an aluminum identification tag wired to a steel rebar stake. In all replications, treatments were assigned randomly in groups of five planting sites. During 2-11 January 1989, acorns were planted the same compass direction and distance from the steel stakes by use of a template in the shape of an equilateral triangle with 10.2-cm sides. For one-acorn sites, an acorn was planted at the top angle and at each angle at three-acorn sites.

Two tools were used to plant the acorns at the proper depth. Whenever possible, a 2.5-cm diameter soil-sampling tube, marked with depth gradations (1.3, 5.1, and 10.2 cm) was used. At unusually rocky planting sites, holes were dug with a 3.8-cm diameter soil auger. The augered holes were measured with a ruler to ensure proper depth for planting. Soil removed with the soil-sampling tube or auger was replaced and firmed against the seed.

To minimize competition from grasses and forbs, herbicides were applied to the site twice: 1.1 kg atrazine and 0.7 kg oxyfluorfen per ha on 14 and 15 February and 1.1 kg glyphosate per ha on 10 March 1989. A backpack spray pump was used to make 1.5-m swaths centered on each row.

## Site Monitoring

On-site rainfall was measured with a Taylor rain gauge. Rainfall data was taken after each storm from January to May 1989. Rainfall data for the same months was obtained from the US Weather Bureau, Salinas Dam Weather Station (3 km east of the study site). Average annual rainfall for the study site was obtained from the US Weather Bureau, Paso Robles, California (33 km north of the site).

Two soil samples were taken from the site in March 1989 and analyzed by the Soil Science Department, California Polytechnic State University, San Luis Obispo. The two locations for the samples were determined ocularly to represent the extremes in soil that occurred.

In order to document the kinds of animals present on the site, live trapping and observational animal scans (Fagerstone 1984) were conducted during March and April 1989. Trapping sites were laid out on a 11- by 11-meter grid. There were 49 trap sites consisting of forty 7.6-cm and nine 12.7-cm Sherman live traps. Trapping was done twice: 8-9 and 21-23 March.

During 15 March to 3 April, a total of 1710-minute periods of observation was made with a pair of field binoculars from a vehicle parked along a blacktop road about 20 m from the exclosure. Number of animals seen on and around the 0.6-ha study plot was recorded. Animal sign and species occurrence was not documented prior to study start up and planting, but cursory observations did not indicate any appreciable differences from during the study.

## Oak Monitoring

Above-ground animal depredation was monitored twice a week during January to March. Acorn depredation was determined by examining each planting site for digging and other signs of animal activity, such as acorn shell remains. Suspected depredation was confirmed ocularly at 1.3-cm planting sites and by examining manually the digging for acorns planted 5.1 cm deep. Since the 10.2-cm depth was too deep for these methods, a ruler was inserted into the hole to measure the depth of digging and to feel for an acorn.

Seedling emergence data was collected weekly from the time the first seedling emerged in March and until emergence of the last seedling in July. Seedlings were located by ocular examination of each planting site. Upon emergence, each seedling was protected from animal damage with a 13-cm diameter aluminum-screen cage pinned to the ground.

Seedling survival and growth data were recorded in October 1989. Survival was determined ocularly. Each seedling was placed in one of two categories: alive or dead. All leaves had to be completely brown for the seedling to be dead. Seedling height was measured (nearest cm) from ground level to the tip of the terminal bud. One outside row (32 planting sites) was omitted from the analysis of height data because of heavier herbicide application.

## Fate of Acorns Not Emerged

Since acorns could have been depredated from underground, a sample of acorns that did not appear to be depredated, but did not produce a seedling, was dug up to determine their fate. In December 1989, 20 planting sites in each of the four replications (118 acorns) were selected randomly for sampling. Each site was dug to the proper planting depth with a shovel and the soil sifted to help ensure finding the acorns, if present.

## Data Analysis

For analysis of animal depredation, the three-acorn planting sites were considered depredated only when all three acorns were gone. For seedling emergence analysis, only one seedling had to come up at a site for it to be successful. If more than one seedling emerged at a three-acorn site, the tallest living seedling in October 1989 was used to assess seedling survival and height. This approach seemed reasonable at three-acorn sites because a practical application of planting multiple acorns is to increase the chance that one vigorous seedling is produced.

General trends of the data were determined using Macintosh EXCEL. Macintosh Statview II (Feldman and others 1987) was used to perform ANOVA to test the treatment effects on percent depredation, emergence, and survival. A multiple-factor factorial, non-repeated measures, balanced model (Winer 1971) was used to compute the ANOVA table shown at top of next column:

| Source | degrees of freedom |
|---|---|
| Planting Depth | 2 |
| Species | 1 |
| Number of Seeds | 1 |
| Planting Depth by Species | 2 |
| Planting Depth by No. of Seeds | 2 |
| Species by No. of Seeds | 1 |
| Planting Depth by Species by No. of Seeds | 2 |
| Blocks | 3 |
| Error | 33 |
| Total | 47 |

If there were significant interactions among any of the treatments (species, planting depth, and number of acorns per planting site) for any variable (acorn depredation; seedling emergence, survival, and height), the table of interaction means was examined to determine the cause of the interaction and how it may affect interpretation of the significant main effects. For each variable, a Duncan's multiple-range test (Steel and Torrie 1960) for the main effects was conducted to determine which treatment means were significantly different at the $P \leq 0.05$ level. Since seedling height data had an unequal number of observations, Student's *t*-tests were used to test the significance of seedling height differences for each of the three treatments.

In table 1, rainfall is compared between 1988 and the year of the study, 1989. Table 2 shows the means of the variables (acorn depredation; seedling emergence, survival, and growth) for the treatments (acorn species, planting depth, and number of acorns per planting site). Figure 2 illustrates the differences in means of the acorn depredation and seedling emergence variables for the species, acorn depth, and number of acorns per planting site treatments.

# RESULTS

## Site Monitoring

The year 1989 was very dry for San Luis Obispo County (US Weather Bureau, Sacramento, California). At the Salinas Dam Weather Station only 26 cm of rainfall were recorded compared to an average annual rainfall of 53 cm. During the first five months of 1989, 14.6 cm of rain fell on the study plot

**Table 1**—***Rainfall (cm) recorded at the Salinas Dam Weather Station during January to May in 1988 compared to rainfall recorded during the same months in 1989 on the study site.***

| | Year | |
|---|---|---|
| Month | 1988 | 1989 |
| January | 7.2 | 3.6 |
| February | 5.1 | 4.1 |
| March | 4.7 | 5.3 |
| April | 7.1 | 0.8 |
| May | 0.2 | 0.8 |

**Table 2**—Average fate of 960 sites planted at three depths: 1.3 (0.5 in), 5.1(2 in), or 10.2 cm (4 in), with either one (1) or three (3) valley (V) or blue (B) oak acorns per site during January to October 1989 on the Santa Margarita Ranch study plot, San Luis Obispo County, California.

| Acorn Planting Depth (cm) | Depredation (pct)[d] | | | | Emergence (pct)[d] | | | | Survival (pct)[d] | | | | Height (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V | | B | | V | | B | | V | | B | | V | | B | |
| | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| 1.3 (0.5 in) | 100 $^{a}$ | 86 | 75 $^{a}$ | 45 | 0 $^{a}$ | 4 | 23 $^{a}$ | 51 | 0 $^{a}$ | 4 | 20 $^{a}$ | 50 | - $^{a}$ | 9 | 6 $^{a}$ | 8 |
| 5.1 (2.0 in.) | 75 $^{b}$ | 50 | 18 $^{b}$ | 0 | 9 $^{a}$ | 23 | 34 $^{a}$ | 63 | 5 $^{a}$ | 20 | 25 $^{a}$ | 55 | 4 $^{a}$ | 10 | 6 $^{a}$ | 7 |
| 10.2 (4.0 in.) | 29 $^{c}$ | 28 | 6 $^{b}$ | 6 | 5 $^{a}$ | 28 | 13 $^{b}$ | 28 | 5 $^{a}$ | 25 | 10 $^{b}$ | 25 | 7 $^{a}$ | 9 | 5 $^{a}$ | 6 |

[a,b,c]Pairs of means (averaged over number of seeds) not followed by the same letter within a column are significantly different ($P \leq .05$) by Duncan's multiple-range test and, for height, by Student's *t* tests.
[d]All percentages are based on 960 planting sites.

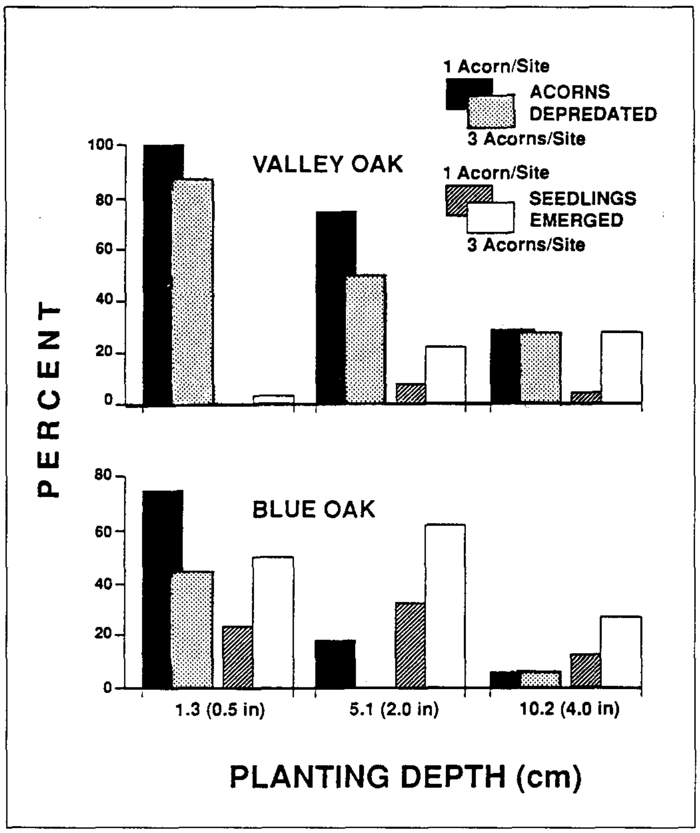


**Figure 2**—Percent valley oak and blue oak acorns depredated and seedlings emerged from three planting depths (1.3, 5.1, and 10.2 cm) at one- and three-acorn planting sites on the Santa Margarita Ranch study plot, San Luis Obispo County, California.

compared to 24.3 cm recorded at the Salinas Dam Weather Station during the same months in 1988 (table 1).

Since the results of the two soil tests were similar, they are averaged here. The soil texture was a sandy loam comprised of 75 pct sand, 12 pct silt, and 13 pct clay. It held only 24 pct water at saturation. The pH was 6.2. Organic matter (nitrogen: 89 kg per ha) was more than average for the soils of the area and, due probably to the residual from grazing, the phosphorus was very high (69 ppm dry weight). Potassium, calcium, and magnesium (123,623, and 41 ppm dry weight, respectively) were all low due to leaching of the sandy soils and because the soils had low ability to retain nutrients.

In March 1989 during the first trapping period, 28 deer mice (*Peromyscus maniculatus*) were caught in Sherman live traps (98 trap nights) and nine during the second period of trapping (147 trap nights). No other animals were captured. Fresh California ground squirrel (*Spermophilus beecheyi*) digging was common after March within and around the study plot. The fact that ground squirrels were not trapped in any of the 12.7-cm Sherman live traps may be due to trap design: the live traps had aluminum rather than woven-wire sides. Ground squirrels are relatively wary of entering the aluminum traps (R. Schmidt, pers. comm.).

California ground squirrels were observed during the seventeen 10-minute observational scans: three times on the study site and 32 times on the surrounding area. No other potential mammal acorn depredators were sighted within or around the study plot. Potential avian depredators were not seen on the site. Although periodic checks were made during January to October 1989, pocket gopher (*Thomomys* spp.) mounds were observed only on the area outside the study plot.

## Oak Monitoring

There were significant differences for the variables acorn depredation, seedling emergence, survival, and height for most levels of the three treatments (oak species, depth the acorns were planted, and the number of acorns planted per planting site) of this study. There were also significant species by planting-depth interactions; valley oak and blue oak did not respond (in terms of acorn depredation, seedling emergence, and survival) in the same way to the depth the acorns were planted. Each variable is explained below.

*Acorn Depredation.*— Of the 960 planting sites, nearly half (43 pct) were depredated. Valley oak acorns were depredated significantly more (61 pct) than blue oak (25 pct).

Depredation was also much different among planting depths, ranging between 100 pct at one-acorn sites for valley oak planted 1.3 cm deep to 0 pct at three-acorn sites for blue oak planted 5.1

cm deep. Depredation of valley oak acorns decreased from 93 pct at 1.3-cm planting depth to 29 pct at 10.2 cm; with one and three-acorn sites combined, these differences were significant. In contrast, blue oak depredation decreased significantly from 60 pct at the 1.3-cm depth to 9 pct at 5.1 cm, but did not change significantly between the 5.1 and the 10.2-cm (6 pct) depths. The fact that animal depredation of valley oak acorns decreased about equally between planting depths but blue oak did not, resulted in a significant oak species by planting depth interaction. Finally, for blue oak and valley oak acorns planted at 1.3 and 5.1 cm, depredation was significantly less at three- than one-acorn planting sites. This difference did not occur at the 10.2 cm planting depth where depredation was nearly equal.

Depredation of acorns began within about a week of planting and continued until mid-March, when emergence of non-depredated acorns began. Occasional depredation of acorns occurred until the end of July. At most planting sites that were depredated, a small hole about 3 cm in diameter was dug, apparently by deer mice, to the depth the acorn was planted. A much greater amount of digging at other depredated planting sites suggested the acorns were taken by ground squirrels. There was no evidence of digging at planting sites by any other kind of animal.

*Seedling Emergence.*—Valley and blue oak seedlings emerged from mid-March to the end of June. A seedling came up at 23 pct of the 960 planting sites. Seedlings grew at significantly more blue oak (35 pct) than valley oak (12 pct) planting sites.

Few valley oak seedlings emerged (4 pct) at the 1.3-cm sites. At the 5.1- and 10.2-cm planting sites, about equal proportions emerged (16 pct and 17 pct, respectively). On the other hand for blue oak, the most (49 pct) seedlings emerged at the 5.1 cm planting depth; significantly fewer (21 pct) emerged at the 10.2-cm depth. This between-species difference in seedling emergence accounts for the significant species by planting depth interaction—the lowest seedling emergence for valley oak was at 1.3 cm planting depth but at 10.2 cm for blue oak. Finally, one-acorn sites produced significantly fewer seedlings than three-acorn sites: 5 pct vs. 18 pct and 23 pct vs. 47 pct for valley oak and blue oak, respectively.

*Seedling Survival.*—Nearly all the blue oak and valley oak seedlings that grew in spring 1989 (a seedling at 23 pct of the 960 planting sites) were still alive the following October (a seedling at 20 pct of the planting sites) when the last data on seedling survival were taken. Therefore, results of the ANOVA for seedling survival are nearly identical to those for seedling emergence: the same significant differences on survival were detected between species, acorn planting depth, and numbers of acorns planted per planting site. Also similar to the emergence results, there was a significant species by planting depth interaction for seedling survival.

*Seedling Height.*—The average height of all seedlings in October at the end of their first growing season was 7.0 cm. Valley oak seedlings were significantly taller than blue oak seedlings (8.3 cm and 6.5 cm, respectively) but, importantly, average heights of valley and blue oak seedlings from acorns planted at 1.3-, 5.1-, and 10.2-cm depths were about the same (9.0, 8.2, and 8.3 cm tall, respectively, for valley oak; 6.8, 6.7, and 5.8 cm tall, respectively, for blue oak). Finally, average seedling height was greater at three- compared to one-acorn planting sites (9.2 and 5.2 cm tall for valley oak; 6.8 and 5.8 cm tall for blue oak); the difference was significant for valley oak.

### *Fate of Acorns Not Emerged*

In December 1989, we searched for 118 acorns (80 planting sites) that had not apparently been depredated nor produced a seedling. Of these, 70 pct had produced both a root and a sprout, but the sprout had not grown above the surface of the ground, and 12 pct appeared inviable. The fate of the remaining 18 pct, which were not found, could not be determined, but there was no evidence of animal depredation.

## DISCUSSION

### *Planting Depth: 1.3 vs. 5.1 vs. 10.2 cm*

Acorns planted at 1.3 cm were more easily detected by deer mice and ground squirrels present in the study plot than those planted deeper (5.1 or 10.2 cm). Observational scans and live trapping on the study plot indicated these surface-feeding rodents were quite common. The acorns planted just below the soil surface were especially susceptible to depredation from above ground. But, even if the acorns had not been depredated, other studies (Griffin 1971; Russell 1971; Johnson and Krinard 1985) indicate they might not have germinated due to adverse soil conditions near the surface: temperatures average higher and evaporation of soil moisture occurs at a faster rate. In this study, these conditions were compounded by the low rainfall and the sandy soils with low water-holding capacity.

On the other hand, the deeper-planted acorns, especially those planted at 10.2 cm, were depredated less because they were less easily detected by smell and the small rodents present on the study plot generally do not dig deep to get acorns (Russell 1971; Johnson and Krinard 1985; Borchert and others 1989). Had gophers been active in the study site, depredation of the more deeply-planted acorns would have likely been greater (Russell 1971).

It is not completely clear why many of the acorns that germinated at a depth of 10.2 cm did not come up. The long-term grazing of the study site has likely compacted the soil, making soil penetration more difficult. Matsuda and McBride (1987) attributed mortality of germinated blue and valley oak acorns to hard soils that did not allow root penetration. But, in this study, it seems that compacted soil would have equally impeded seedling emergence of acorns planted at depths of 1.3 and 5.1 cm. Especially for blue oak, planting 10.2 cm deep apparently resulted in such a large distance for the shoots to penetrate that many were not successful in emerging from the soil.

It is of interest that in spite of the environmental conditions at the study site and acorn physiological constraints, in contrast to blue oak, valley oak seedling emergence and survival did not decrease between the two deeper planting depths. Our data do not provide enough evidence to adequately judge this observation, but it suggests that the relatively large valley oak acorns may produce a seedling from acorns planted quite deep. Moreover, especially for valley oak, had rainfall been average and/or the soil had higher water-holding capacity, seedling emergence from the deepest planting depth (10.2 cm) may have been much better. Because of the advantage of lesser animal depredation that planting acorns at deeper depth affords, it may be useful to test success of deep-planted acorns under several water (rainfall) and soil conditions.

### *Species: Valley Oak vs. Blue Oak*

The planting depth by oak species interactions in the ANOVA tests indicated that these factors acted together on acorn depredation, seedling emergence, and seedling survival. A possible explanation for greater depredation of valley oak acorns compared to blue oak, even at deeper planting depths is, simply, that valley oak acorns are larger. Barnett (1977) did a study with pignut hickory (*Carya glabra*) and white oak (*Quercus alba*) in which the hickory was depredated at a higher rate than the oak. Barnett attributed this to the stronger odor of the hickory nut due to its larger size; it was easier than the smaller white oak for predators to locate. Similarly in this study, the larger valley oak acorns may have exuded a stronger odor which attracted predators more, even at the deepest planting depth. It seems unlikely that use of the fungicide Captan on the valley oak, but not on blue oak acorns, increased depredation differentially. According to Sid Sakamoto (pers. comm.), Captan does "not attract small mammals." In fact, for seed-eating birds, Captan has been used as a repellent.

### *Number of Seeds: One vs. Three*

This study confirms the validity of the acorn-planting technique: several acorns per spot. Three-acorn planting sites had less acorn depredation and better seedling emergence, survival, and height. Notably, apparently 10.2 cm (4 in) was adequate space between acorns to minimize the likelihood of finding all three once one was located—at least for the kinds of animal depredators on the study plot. The higher emergence and survival rates at three-acorn sites indicates that competition between seedlings was not a problem during the first growing season. Greater average height, moreover, of seedlings at three-acorn sites was due, simply, to the opportunity to select the tallest of three seedlings. The advantages of planting multiple acorns are noteworthy because acorns are easy to collect and planting several per planting site is not much more expensive or difficult than planting one.

## RECOMMENDATIONS

The following management recommendations are suggested:

(1)Plant acorns about 5.1 cm (2 in) deep. This will help reduce animal depredation but not be too deep for seedlings to come up. Somewhat deeper planting may be better in areas or years of high rainfall and/or soil with good water-holding capacity.

(2)Plant several seeds per planting site, spaced at least 7 cm (several inches) apart.

(3)Plant the oak species which is most suited to the rainfall and soil conditions of the area.

Planting at the recommended depth does not preclude the need to protect the planting site. Planting at the optimal depth may increase the chance of success of protected sites, and may make successful planting more likely when protection of the planting site is not practical.

## ACKNOWLEDGMENTS

We thank D. McCreary for the lead in acquiring funding for this project and the California Conservation Corps for constructing the fence exclosure around the study plot. The Santa Margarita Ranch kindly allowed access for study purposes. Assistance with Statistical analysis was provided by C. Adams, Statistician, University of California, Riverside. This study was funded by California Department of Forestry and Fire Protection Grant 8CA74639 and the University of California Integrated Hardwood Range Management Program.

## REFERENCES

Adams, T. E.; Sands, P. B.; Weitkamp, W.; McDougald, N. K.; Bartolome, J. 1987. Enemies of white oak regeneration in California. In: Proceedings of the symposium on multiple-use management of California's hardwood resources, 1986 Nov. 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 459-462.

Barbour, M.; J. Major (Eds.). 1988. Terrestrial vegetation of California. Sacramento, CA: California Native Plant Society; 1020+ p.

Barnett, R. 1977. The effect of burial by squirrels on germination and survival of oak and hickory nuts. American Midland Naturalist 98(2): 319-330.

Borchert, M.; Davis, F.; Michaelsen, J.; Oyler, L. 1989. Interaction of factors affecting seedling recruitment of blue oak in California. Ecology 70(2): 389-404.

Fagerstone, K. 1984. An evaluation of visual counts for censusing ground squirrels. In: Vertebrate Pest Control and Management Materials, Fourth Symposium. Philadelphia, PA.; 1982 February 26; Monterey, CA. American Society for Testing and Materials, Authorized Reprint from STP 817; 239-246.

Feldman, D.; Hofmann, R.; Gagnon, J.; Simpson, J. 1987. StatView II: The solution for data analysis and presentation graphics .Berkeley, CA: Abacus Concepts, Inc.

Griffin, J. 1971. Oak regeneration in upper Carmel Valley, California. Ecology 52(5): 862-868.

Johnson, P.; Dale, C.; Davidson, K.; Law, J. 1986. Planting northern red oak in the Missouri Ozarks: a prescription. Northern Journal of Applied Forestry 3:66-68.

Johnson, R.; Krinard, R. 1985. Regeneration of oaks by direct seeding. In: Proceedings, Third symposium of southeastern hardwoods; 1985 April 16-17; Dothan, AL. Proceedings Reprint. New Orleans, LA: Southern Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 56-65.

Johnson, R.; Krinard, R. 1987. Direct seeding of southern oaks—a progress report. In: Proceedings, fifteenth annual hardwood symposium of the hardwood research council; 1987 May 10-12; Memphis TN. Proceedings Reprint. New Orleans, LA: Southern Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 10-16.

Matsuda, K.; McBride, J. 1987. Germination and shoot development of seven California oaks planted at different elevations. In: Proceedings, symposium on multiple-use management of California's hardwood resources; 1986 Nov 12-14; San Luis Obispo, CA. Gen. Tech. Rep. PSW-100. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 79-85.

McCreary, D. 1989. Emergence and growth of blue and valley oak seedlings as affected by acorn sowing date. In: Proceedings, tenth North American forest biology workshop; 1988 July 20-22; University of British Columbia, Vancouver, B.C. Atlanta, GA: Department of Forest Science, University of British Columbia and Society of American Foresters; 200-203.

Russell, T. 1971. Seeding and planting upland oaks. In: Proceedings, the oak symposium; 1971 Aug 16-20; Morgantown, WV. Upper Darby, PA: Northern Forest Service Experiment Station, Forest Service, U.S. Department of Agriculture; 49-54.

Sakamoto, S., Technical Service Representative for the Valent Corporation, Sacramento, CA. [Telephone conversation with Sherryl Nives]. February 15, 1990.

Schmidt, R., Natural Resource Specialist, Department of Forestry and Resource Management, University of California, Berkeley. [Study site visit with W. Tietje]. March 29, 1989.

Steel, R.; Tome, J. 1960. Principles and procedures of statistics. New York, NY: McGraw-Hill Book Co., Inc; 481 p.

Vande Linde, F. 1987. Oak plantation—establishment and management. In: Proceedings, fifteenth annual hardwood symposium of the hardwood research council; 1987 May 10-12; Memphis TN. Proceedings Reprint. New Orleans, LA: Southern Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 57-61.

Winer, B. 1971. Statistical principles in experimental design. New York, NY: McGraw-Hill Co., Inc.; 907 p.

Wright, G.; Pope, P.; Fischer, B.; Holt, H.; Byrnes, W. 1985. Chemical weed control to establish natural and artificial oak regeneration in a mechanically thinned upland hardwood stand. In: Proceedings, third biennial Southern silvicultural research conference; 1984 November 7-8; Atlanta, GA. New Orleans, LA: Southern Forest Experiment Station, Forest Service, U.S. Department of Agriculture; 266-272.