Improving the Sustainability of Oak Woodland Forage and Productivity in San Diego County Through the Exploration for and Introduction of Nitrogen Fixing Annual Legumes[1]

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Abstract: The oak woodlands of San Diego County are below their potential productivity due to the low levels of the most needed plant nutrient, nitrogen, associated with the common soils of this zone. Atmospheric nitrogen fixing legumes could address this deficiency. However, because of limiting environmental constraints, adapted commercial legume cultivars have not been available. By the early 1980's, a modest plant exploration program was begun to identify annual legumes with potential for adaptation to this region, locate them in their native or naturalized habitat, collect and reproduce an adequate number of these legumes' wild types and test them for adaptation. Trials established in 1984 and evaluated over a 4-year period indicate that a number of these wild legumes are adapted and are superior to presently available Australian cultivars. These encouraging results suggest continued testing and screening of legume materials that address the soils' nitrogen deficiency in the oak woodland rangelands of Southern California.

Oak woodlands constitute a small portion of the total acreage of San Diego County (3.9 percent), yet this vegetation type, both a dense phase near streams and a sparse phase of Savanna-type conditions covers approximately 107,000 acres.

These oak woodlands are considered the most valuable range and wildlife habitat area of this region. The common oak trees of this zone are the California black oak (*Quercus kelloggii* Newb.), coast live oak (*Q. agrifolia* Née), canyon live oak (*Q. chrysolepis* Liebm.), and Engelmann oak (*Q. engelmannii* Greene). While reports by Pillsbury and others (1983) and Mayer and others (1986) pointed out that in some parts of the State of California some oak types are not regenerating well, the failure to regenerate is thought to be poorly understood and a catch-all phase to explain this phenomena is, "...long-term trends in climate, fire history, invasion of non-native grasses, cultivation, browsing of cattle and wildlife, and movement of people into wildland areas" (Adams and others 1988).

In San Diego County, fire exclusion may be the most important factor for oak stand degradation and the lack of adequate regeneration (Biswell 1989). Very poor results have been reported with attempts at artificial regeneration from seeded acorns and from nursery stock (Adams and others 1988).

Because cattle and wildlife browsing has been accused of being an important factor in oak regeneration, it is hypothesized that an improvement in the forage component palatability of the grasslands associated with the oaks of this zone would be a good practice to implement to divert the browsing pressure away from oak seedling regeneration and establishment. Yet range studies in this vegetation type show that forage production is low and quality poor during an important part of the year. Important contributing factors are the soils and annual vegetation types in these zones. Soils are usually deficit in nitrogen. Productivity and quality of the naturalized annual vegetation is low. Animal performance is poor without costly external inputs of nitrogen fertilizer.

Production of nitrogen fertilizer, a key element for obtaining high production on these range areas, requires high energy and fossil fuel inputs for its commercial production (Green 1978). Since the energy crisis of 1973, and the Middle East situation of 1990, nitrogen fertilizer produced from natural gas has become a questionable resource for improving range forage production. Still the potential of this vegetation type is at least twice that of its present production due to the low level of soil nitrogen in this zone.

Nitrogen fixing legumes are a vegetative component which could be introduced into this zone to correct this deficiency. The introduction of annual legumes adapted to a Mediterranean climate and capable of biologically fixing significant amounts of nitrogen, is promising. However, our successful early introductions of subclover and other annual legumes to northern California, were highly dependent on adequate well distributed rainfall (Murphy and others 1973). Rainfall amounts and distribution are much less dependable in southern California. Because of this zone's limiting environmental constraints, legume cultivars adapted to this oak woodland zone have not been available (Helphinstine and others 1983).

In order to properly address this interest, a legume germplasm base was needed on which to build a research and development program. Since the initiation of the Plant Introduction program in 1899, the USDA has been quite active in its research for better plant materials on a worldwide basis. Yet, as late as 1979, only a very limited number of range legume introductions had been made that performed well in California's Mediterranean climate (White and Oakes 1979).

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By 1980, a modest plant exploration program was begun to identify annual legumes that have the potential for adaptation to this region, locate them in their native and/or naturalized habitat, and collect and reproduce an adequate number of wild strains for adaptation trials in this oak rangeland zone. It is the objective of this paper to report on our legume exploration program and the development and testing of selected accessions for adaptation in the oak- grassland vegetation zone of San Diego County.

LEGUME EXPLORATION AND BACKGROUND

Our initial exploration project was begun in Tunisia and reported in Graves and others (1988). Although this plant collection represented 332 indigenous legume accessions, the plant materials did not cover sufficient enough mountain elevation zones to have the potential for resisting the winter cold of our oak woodland range. We expanded our program in 1983 to include a collection trip to Morocco (Rumbaugh and Graves 1985). We were able to choose collection zones in Morocco by using a climate classification system developed by Emberger (1955) based on average monthly rainfall and temperature. We were able to match with good approximation sites from the oak woodland zones of San Diego County and similar vegetation and climate zones of Morocco. An example of this climatic match is presented in table 1. This collection added another 900 accessions to our national germplasm bank. More than two-thirds were legumes and expanded considerably the diversity of our legume species and their adaptive potential.

These introductions were considered of extreme importance for germplasm preservation in light of Morocco's late 1970's and early 1980's droughts and subsequent vegetation degradation.

Table 1—*Average monthly rainfall and mean temperatures for Wynola,* San *Diego County and Similar Mediterranean climate analog in Morocco (El-Hajeb)*

Month	Average Rainfall-(in)		Mean Temperature (°F)	
	Wynola	El-Hajeb	Wynola	Morocco
July	0.44	0.11	69.5	75.6
August	0.53	0.20	69.6	76.9
September	0.79	0.74	65.7	69.1
October	0.74	2.56	58.4	61.8
November	2.68	3.78	50.5	52.9
December	2.68	3.35	46.2	46.7
January	4.69	2.71	43.7	45.1
February	3.76	2.95	45.1	47.1
March	4.08	3.19	46.1	50.7
April	2.79	3.30	50.4	51.6
May	1.26	2.09	53.8	60.2
June	0.16	0.78	60.9	67.9
Year Ave	24.60	25.78	55.0	59.2
Elev. (ft)	3,655	3,454		
Latitude	33°06'N	33°41'N		

MATERIALS AND METHODS

Seed Increases

At this point we believed that we had adequate legume germplasm to test our hypothesis of adaptability of plant materials from the Mediterranean zone to an analog climate in California. These collections were placed in a seed increase nursery at the University of California Riverside Experiment Station in the 1983-84 growing season. During this initial seed increase year, we were able to make preliminary observations on winter vigour, days to flowering, biomass and seed production that allowed us to screen for accessions that would have the best potential for adaptation in our oak woodland areas. During the summer of 1984, all seed increase plots were harvested, shelled, cleaned, inventoried and targeted for future field testing.

Field Trial

During the 1983-84 season, we solicited cooperators for field testing our legume introductions in a typical oak grassland range area. In early 1984, we selected Spike Alford Ranch in the Mesa Grande area of San Diego County with the USDA Forest Service (Cleveland National Forest) as an interested collaborator.

The test site is located at 3,200 feet elevation and approximately 3 miles of Mesa Grande adjacent to the Mesa Grande Truck Trail. The zone is oak grassland of coast live oak, an occasional black oak and canyon live oak. The associated grasslands species are typical naturalized annuals, mainly filariae (*Erodium* sp.) and annual bromes (*Bromus* sp.). The soils of this area are of the Holland series, fine sandy loam, slightly acid pH, 5-10 percent slope (fine-loamy, mixed, mesic, Ultic Haploxeralfs) with very low phosphate levels. Average annual rainfall, as estimated from the nearby weather station of Wynola, is 24.6 inches for July 1 through July 30. The average seasonal effective rainfall for growth annual species from September 1 through May 31 is estimated to be 23.6 inches. Most of this precipitation occurs from November through the April period with the dry period usually extending from early May through October. Seasonal and monthly precipitation is highly variable in this zone (Graves and others 1988).

The trial consisted of 20 entries of 11 subclover (*Trifolium subterraneum* L.) accessions from Morocco, four Australian subclover cultivars, three naturalized rose clovers (*T. hirtum* All.) from Northern California and two Australian rose clover cultivars. Establishment method consisted of an application of

single superphosphate (0-18-0) at 200 lbs/acre and a light discing of the soil surface to prepare the seedbed. On October 2,1984, seeds of each of the entries were broadcast on replicated plots, 4 ft x 4 ft, in a randomized block design at a 50 lb/acre rate and raked to cover lightly. All the seeds were freshly pellet-inoculated at the rate of 5 lbs of inoculant per 100 lbs of seed (Pelinoc[3] inoculating system, Milwaukee, Wisconsin).

The plots were located in an open range pasture and were not fenced to exclude grazing. The pasture with the test plots received continuous moderate grazing by cattle during the late winter and spring growing season for the establishment year through the 4-year evaluation period. Stand cover evaluations were made near the end of each growing season by visually rating plot cover on a 0-10 scale (0=no plants, 10=complete ground cover). Stand regeneration is thus defined as the annual clover's ability to regenerate its cover within the planted plot. The most recent stand persistence evaluations were made on March 29, 1988. Flowering also was observed on the date of the rating. Stand regeneration evaluations were analyzed statistically for strain differences.

RESULTS AND DISCUSSION

The results from this trial are very encouraging and exciting. Three of the Moroccan accessions of subclover showed exceptionally good adaptation (regeneration) and were covering their seeded plots (see table 2). As one can see from this ranking, the experimental accession GR 508 (PI 517171) and GR 565 (PI 517173) were superior to all other entries, and much better than the Australian commercial subclover cultivars, Seaton Park, Northam, Geraldton or Nungarin.

The Australian rose clover cultivars, Hykon and Kondinin, showed some degree of persistence, as did the naturalized collections from Shasta, Siskiyou and Mendocino Counties. These three naturalized rose clover collections are much later in maturity than the two rose clover cultivar entries and we would expect these accessions to be at a disadvantage in this zone due to its short rainfall season. Thus, we would not expect these accessions to persist and regenerate during years of low rainfall (drought). We believe that these results are a good indication of accession adaptability in this zone, since all entries had an equal opportunity for establishment from the initial seeding (first season plot coverage evaluation ratings were not significant and thus the rating was not reported here). Therefore, we believe that long- term persistence of these accessions will not be affected by initial establishment.

[3]Disclaimer: To simplify information, trade names of products have been used. No endorsement of named products is intended nor is any criticism implied of similar products which are not mentioned.

Table 2—*Subclover and rose clover entries regeneration and flowering evaluations at the Alford Ranch, Mesa Grande, San Diego County, end of fourth growing season*

Variety/Accession	Ranking/Plot Coverage (0-10, 10=100 pct Coverage) Average of 4 Reps	Flowering on 3/29/88 (+=flowers, - = no flowers)
GR 508 Sub (PI 517171)	8.8	+
GR 565 Sub (PI 517173)	7.2	+
GR 567 Sub (PI 517174)	6.2	+
Shasta 4300' Rose	5.8	-
Kondinin Rose	5.0	+
Siskiyou Rose	5.0	-
Mendocino Rose	5.0	-
Hykon Rose	4.5	+
Seaton Park Sub	4.2	+
Northam Sub	3.5	+
GR 435 Sub (PI 517164)	3.2	+
Geraldton Sub	2.2	+
GR 448 SUB (PI 517167)	2.0	-
GR 450 Sub (PI 517168)	1.8	-
GR 316 Sub (PI 517155)	1.8	+
GR 436 Sub (PI 517165)	1.8	-
GR 494 Sub (PI 517170)	1.2	+
GR 519 Sub (PI 517172)	1.2	-
Nungaran Sub	1.2	+
GR 301 Sub (PI 517154)	1.0	+
LSD (0.05)	1.5	

Note: All varieties/accessions that are not flowering at this time will probably no regenerate this year since the effective rainy season is short this year and the plot have not had rain for some 4 weeks.

We present the monthly growing season precipitation information for the 1984 establishment year through the 1988 growing and final evaluation season in table 3. The rainfall totals for the growing seasons were below average in three of the four growing seasons over which evaluations were made. This factor also lends further credence to our belief that the showing of at least three of our Moroccan wild type experimental accessions have the potential for long-term regeneration and adaption to this oak woodland zone of San Diego County.

Table 3—*Growing season (September 1 through May 31) monthly rainfall covering the period of the evaluation (October 1984 to May 1988)*

Year	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
84-85	—	0.5	3.0	7.4	2.3	2.1	2.8	1.1	0.1	19.3
86-86	1.8	0.8	8.6	2.2	1.2	6.0	7.6	0.6	0.1	28.9
86-87	2.1	1.4	1.3	2.2	2.8	2.6	3.7	0.7	0.8	17.6
87-88	0.3	4.6	4.1	3.3	4.0	1.8	1.2	—	—	19.3
Average	0.8	0.7	2.7	2.7	4.7	3.8	4.1	2.8	1.3	23.6

SUMMARY

Several factors are considered important in the successful establishment and persistence of subclover and/or other legume stands in this oak- grassland zone of Southern California. These factors are: the choosing of an adapted cultivar, use of phosphate and sulfur fertilizer, pellet inoculation with specific Rhizobium strains (Jones and others 1978), seeding just prior to the rainy season into a properly prepared seedbed, adequate and timely rainfall and animal grazing during the establishment and subsequent life of the legume stand. Grazing during the growing season is important to enhance its establishment and regeneration. Proper grazing can help to control undesirable weeds, optimize seed production, maintain a proper grass-legume balance and increase nitrogen recycling.

Although numerous Australian legume cultivar introductions have occurred over the last several decades, most have been soft seeded cultivars which have had limited success outside of the more favorable and longer season rainfall zones of northern California. Our results encourage continuation of testing and screening for the eventual varietal release of legume materials to address the soil nitrogen deficiency of the oak woodland rangelands of southern California in order to enhance wildlife and livestock habitat and sustain oak regeneration.

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REFERENCES

Adams, T.E.; Sands, P.B.; and Weitkamp, W.H. 1988. Artificial regeneration of blue and valley oak in California. Range Science Report No. 16. University of California, Davis: Dept. of Agronomy and Range Science, 9 p.

Biswell, H.H. 1989. Prescribed burning in California wildlands vegetation management. Berkeley: University of California Press, 255 p.

Emberger, L. 1955. Une classification biogeographique des climats. Recit des travaux de laboratoire de botanic, geologic et zoologie de la faculte de sciences de Montpellier. Scale Botanic 7:3-43.

Graves, W.L.; Kay, B.L.; Jarrell, W.; Burton, J.C.; Wegrzyn, V; Rumbaugh, M.D. 1988. Energy-efficient legumes for California's organic agriculture. 679-688. In P. Allen and D. Van Dusen, Eds. Proc.- Sixth International Conference, IFOAM, Aug. 18- 21, 1986, University of California, Santa Cruz.

Green, M.B. 1978. Eating oil. Boulder, CO: Westview Press, 208 p.

Helphinstine, W.N.; Brown, V.W.; Love, R.M. 1983. Hard seed ensures rose clover survival on rangeland. California Agriculture 37:12-13.

Jones, M.B.; Burton, J.C.; Vaughn, C.E. 1978. Role of inoculation in establishing subclover on California annual grasslands. Agronomy Journal 70:1081-1085.

Mayer, K.E.; Passof, P.C.; Bolsinger, C.; Grenfell, W.E.; Slack, H. 1986. Status of the hardwood resource of California: A report to the Board of Forestry. Sacramento, CA: California Department of Forestry and Fire Protection, 126 p.

Murphy, A.H.; Jones, M.B.; Clawson, J.W.; Street, J.E. 1973. Management of clovers on California annual grassland. Circular 564. Berkeley: University of California Agriculture Experiment Station, 9 p.

Pillsbury, N. (Chair) and others 1983. California's hardwood resource. Preliminary Report of the Hardwood Task Force. Sacramento, CA: State Board of Forestry, 67 p.

Rumbaugh, M.D.; Graves, W.L. 1985. The Medicago germplasm resources of Morocco. PGRC/E. ILCA Germplasm Newsletter 10:12-15, Addis Ababa.

White, G.A.; Oakes, A.J. 1979. Introduction and documentation of forage crop germplasm. In Proceedings of the 36th Southern Pasture and Forage Crop Improvement Conference, May 1-3,1979, Beltsville, MD: Southern Pasture and Forage Crop Improvement Association; 105-111.