Competition Between Grasses Reseeded on Burned Brushlands in California

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SEVERAL thousand acres of burned-over brushlands in California, west of the Sierra Nevada Mountains, are reseeded to grasses and legumes each year. The principal objectives of reseeding are: (1) To supply forage for game and livestock, (2) to provide a plant cover beneficial in lessening soil erosion, (3) to furnish competition to reduce survival of brush seedlings which may appear in great abundance following fire, and (4) to supply fuel for a subsequent reburn to further reduce the brush cover if necessary. Some of the seedings are on wildfire burns, others on areas prescribed or controlled burned.

The present study aims to measure the effect of competition of different densities of an annual grass with several perennials, as far as densities can be controlled by rates of seeding. The annual is domestic ryegrass (*Lolium multiflorum*) and the perennials used are hardinggrass (*Phalaris tuberosa*), tall fescue (*Festuca arundinacea*), and smilo (*Oryzopsis miliacea*). An ultimate aim is to work out combinations of species to plant that will best fulfill the objectives of reseeding. Specific questions to be answered are: (1) What is the relation between the rate of seeding of each species and its density and yield? (2) What is the relation between rate of seeding of ryegrass and the density or yield of each perennial when seeded in combination with the ryegrass? (3) Is the effect of the different rates of seeding of ryegrass on the density or yield of the perennials greater or less than the effect of different rates of seeding of the perennials? Only first year results are being reported here.

Since in some areas all four of the principal objectives in reseeding should be met with about equal urgency, careful consideration must be given to combinations of species best suited for each and all purposes. Working out proper combinations of adapted species is chiefly a problem of plant competition. Observations have already indicated that no single species of plant fully serves all of the objectives of reseeding. As forage for game and livestock, all of the species tested have proven satisfactory. Domestic ryegrass furnishes the most forage the first season after planting but it decreases sharply in yield the second year, whereas the perennials increase in yield after the first year if properly managed. As cover for lessening soil erosion, ryegrass seems to excel the first year but may be equalled by the perennials later on. Ryegrass seed germinates readily; the resulting plants begin to tiller quickly and form a better cover early in the first season than the perennials. For competition with brush seedlings, the ryegrass appears superior to the perennials. It grows rapidly and uses soil moisture so extravagantly that insufficient amounts remain for the brush seedlings, most of which die during the first summer. On the other hand, the perennials are usually slower in becoming established and competition with brush seedlings is not as severe as with the ryegrass. Also in furnishing fuel for a reburn, the ryegrass is superior to the perennials as it forms a denser plant cover and the forage becomes drier during the summer.

The species mentioned above are frequently recommended for reseeding on burned-over brushlands (Love and Jones, 1952). One or more legumes are usually added.

The investigations are carried on cooperatively between the University of California and the California Department of Fish and Game. Work is done under Federal Aid in Wildlife Restoration Act, Pittman-Robertson Research Project California 31-R entitled, "Effects of Brush Removal on Game Ranges in California."

Procedure and Conditions

The design of the experiment is that of a split-plot factorial with four whole plots and six subplots. The whole plots are rates of seeding of the perennials (1, 2, 3, and 4 pounds per acre of hardinggrass and smilo; 2, 4, 6, and 8 pounds per acre of tall fescue) and the subplots are rates of seeding of ryegrass (0, 3, 6, 9, 12, and 15 pounds per acre). The resulting 24 combinations comprise the experimental units, each of which is a plot 25 by 40 feet or .023 acre in size. These combinations were replicated in three blocks. Measurements taken and reported are foliar density, forage yield, and numbers of perennial plants. The analysis of variance for testing the significance of the effects of rates of seeding on each of the above-named measurements was that of the split-plot design (Cochran and Cox, 1950).

The plots were located in the foothills of the Sierra Nevada Mountains in Madera County, at about 2,600 feet elevation. The plant cover before burning consisted of a mixture of trees and brush occurring in the following order of abundance: chaparral whitethorn (*Ceanothus leucodermis*), Mariposa manzanita (*Arctostaphylos mariposa*), interior live oak (*Quercus wislizenii*), digger pine (*Pinus sabiniana*), wedgeleaf ceanothus (*Ceanothus cuneatus*), yerba santa (*Eriodictyon californicum*), and ponderosa pine (*Pinus ponderosa*). A prescribed burn was made in August 1950. The fire was intense, killing the tops of all plants and consuming everything but the larger stems of the live oaks and pine trees. A thick layer of white ash covered the ground. The seed was hand broadcast uniformly over the ashes. In spring after the burn, sprouts of live oak and yerba santa appeared, together with numerous seedlings of the ceanothus species, Mariposa manzanita, and yerba santa. Resident annual forbs were scattered uniformly but nowhere covered more than 10 percent of the ground.

The soil was classified as Holland sandy loam by L. K. Stromberg, Soil Survey specialist, Soils Department, University of California, Berkeley. This is residual soil developed in coarse-grained acid igneous rocks, and ranging from five to six feet in depth. The first eight inches are grayish brown sandy loam with a soft lumpy structure, neutral reaction, and moderately well supplied with organic matter. This grades into a horizon of similar structure but which is slightly acidic in reaction. Between two and five feet the color is pale brown and there is little or no clay accumulation. The surface drainage and percolation capacity of the soil is good.

The average annual rainfall for the area is about 28 inches, usually distributed between October 1 and May 15. Vegetation begins growth soon after the rains start, the growth rate being most rapid in March. Temperatures are a little below freezing occasionally during the winter.

Experimental Results

Domestic Ryegrass—Hardinggrass

The ryegrass-hardinggrass plots were seeded October 4, 1950. The first rain after this was on October 23 and by the end of the month 2.6 inches had fallen, enough to initiate germination. This was followed by 14 inches of rain in November, 8 inches in December, 3.5 inches in January, and 1.5 inches in February, and more later on. Emergence of ryegrass seedlings began during the second week of November and was nearly completed by mid-December. Hardinggrass seedlings on the other hand were slower, beginning to emerge during the first week of December and continuing to come up sporadically as late as mid-January. No systematic seedling counts were made in all the plots but by sampling within randomly selected plots it was found that 47 percent of the ryegrass and 20 percent of the hardinggrass seeds had germinated by the first week of March.

Foliar density

Estimates of foliar density of ryegrass, hardinggrass, and other plants were made in April at a time when approximately half of the final number of tillers of ryegrass had been produced. Sampling was done by placing 21 square-foot quadrats at random within the plots. A five-foot border around each plot was left to insure against contamination of the seeding rates and the possibility of competition from plants in adjacent plots.

TABLE 1

Table of mean squares for analyses of variance of a split-plot design, showing levels of significance for each source of variation

SOURCE OF VARIATION	MEAN SQUARES				
	D.F.	A Density ryegrass	B Density hardinggrass	C Yield ryegrass	D Yield hardinggrass
Replications	2	3,847*	250	305*	597
Rate of perennial	3	416	1,562*	87	1,328*
Linear	1	—	4,143†	—	3,906†
Quadratic	1	—	40	—	76
Deviations from quad	1	—	503	—	4
Error (a)	6	532	283	32	232
Rate of ryegrass	5	9,594†	5,687†	659†	13,972†
Linear	1	23,560†	15,728†	1,139†	34,637†
Quadratic	1	21,765†	9,958†	1,659†	23,793†
Deviations from quad	3	881	913	496*	3,809*
Perennial x ryegrass	15	803	640	39	722
Error (b)	40	273	387	43	418

* 95 percent level; † 99 percent level.

The rate of seeding of hardinggrass with ryegrass had no measurable effect on the density of the latter (Table 1, column A). This might be expected since the rate of germination of hardinggrass was lower than that of ryegrass, and both germination and early growth were slower.

The rate of seeding of ryegrass, on the other hand, had a profound effect on ryegrass density. Figure 1 indicates the relationship. Density increased markedly when the seeding rate was increased from three to six pounds per acre, still more when increased to nine pounds, but was less when increased to 12 and 15 pounds per acre. Individual plants in plots seeded at the lower rates had up to 70 tillers by early April, whereas in the more heavily seeded plots a maximum of 20 tillers per plant were found. Thus, profuse tillering of plants in the sparser stands more than compensates for the greater numbers of seedlings in the thicker stands in contributing to high foliar density.

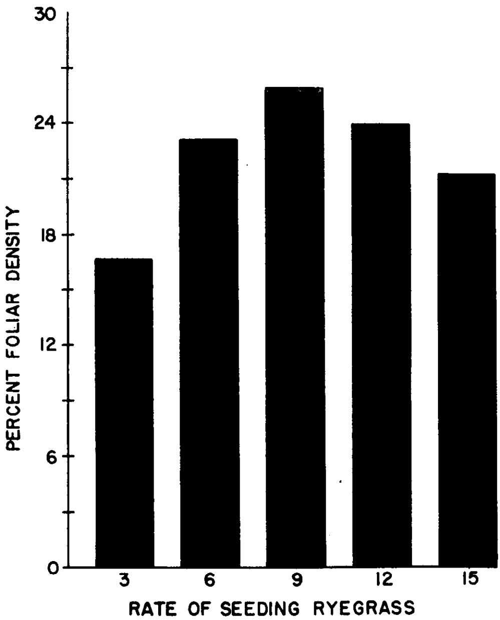

FIGURE 1. Foliar density of domestic ryegrass in April, seeded at five different rates. Approximately one-half of the final number of tillers had been produced.

The complete analysis of variance of the effects of rates of seeding of both hardinggrass and ryegrass on the density of the latter is given in Table 1, column A.

Foliar density of hardinggrass is dependent on the rate of seeding of both hardinggrass and ryegrass. The density of hardinggrass increased significantly and somewhat in direct proportion with each increase of one pound per acre in its seeding rate (Fig. 2, A). When seeded with ryegrass, however, hardinggrass decreased with each increase of three pounds per acre in seeding rate of ryegrass (Fig. 2, B). Densities of hardinggrass ranged from 1.5 to 6.9 percent where ryegrass was not seeded and 0 to 0.5 percent where seeded with 15 pounds per acre, with intermediate densities for the other seeding rates. Although the magnitude of the densities is low, the significance of the differences between them is high (Table 1, column B).

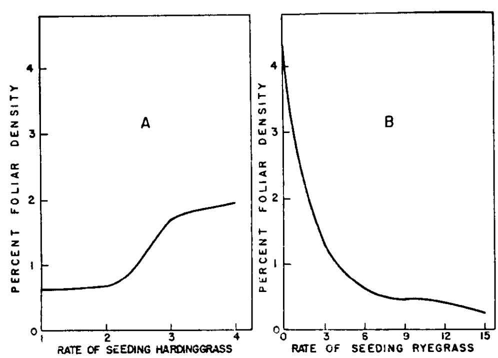

FIGURE 2. Foliar densities of hardinggrass in April (A) resulting from different rates of seeding of hardinggrass, irrespective of the amount of ryegrass seeded with it, and (B) from different rates of seeding of ryegrass.

Hardinggrass density was 71 percent less when seeded with three pounds of ryegrass than when seeded alone; and still another 15 percent less when seeded with six pounds of ryegrass. With each heavier seeding of ryegrass, the hardinggrass density was still lower (Fig. 2, B).

Forage yield

After maturity hardinggrass was clipped from half of each plot; seed heads were dry as well as most of the leaves.

The clipped herbage was weighed air-dry and the yields were computed on a pound per acre basis. Ryegrass was clipped from a transect 1 by 25 feet in dimension, located at random within the same half of the plots from which the hardinggrass was clipped. Ryegrass weights were obtained at time of clipping.

Correlation between yields of hardinggrass and ryegrass and the density estimates made in April was high when all seeding combinations were considered (Table 2). When grouped according to rates of seeding of ryegrass, highest correlation was obtained at the low rates of seeding and the lower correlations at the higher rates of seeding. The nonsignificance of some of the latter correlation coefficients may either be due to an unreliability of ocular estimates when ryegrass density was high or it may result from the effect of a degree of competition in the heavily-seeded ryegrass plots during the interval from April to July differing from that during the interval from germination to April.

TABLE 2

Correlations between forage yields taken in July and density estimates in April

RATES OF SEEDING RYEGRASS	CORRELATION COEFFICIENTS	
	Density vs. yield of hardinggrass	Density vs. yield of ryegrass
0	.821†	
3	.900†	.684†
6	.425	.418
9	.585*	.143
12	.674*	−.106
15	.635*	.418
All plots	.889†	.670†

*95 percent level; †99 percent level.

Yield of ryegrass was maximum when seeded at six pounds per acre (Fig. 3). This is in contrast to the April ryegrass density which was maximum at nine pounds per acre (Fig. 1). The amount of hardinggrass seeded had no significant effect on the yield of ryegrass (Table 1, column C).

Yields of hardinggrass depended both on the rate of seeding of that species and on the amount of ryegrass seed in the mixture (Table 1, column D). The relative effects of these two factors are shown

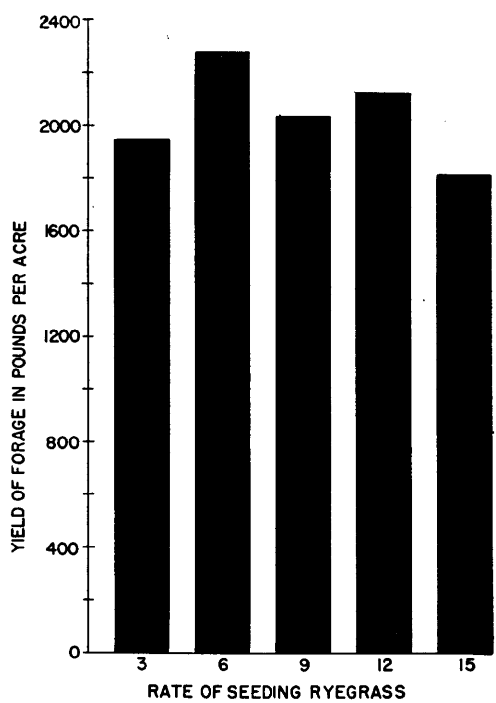

FIGURE 3. Yield of ryegrass in pounds per acre of dry forage when seeded at five different rates. Data taken from ryegrass-hardinggrass plots.

in Table 3 and graphically in Fig. 4. Hardinggrass yields increased linearly with each increment of one pound per acre of hardinggrass seeded, but decreased curvilinearly with each increment of three pounds of ryegrass seeded. Yields of hardinggrass were extremely low when ryegrass was seeded at more than three pounds per acre, regardless of the seeding rate of hardinggrass. In other words, establishment of a good stand of hardinggrass depends far more on how much ryegrass is seeded in combination than on the amount of hardinggrass seeded.

TABLE 3

Yields of hardinggrass in pounds per acre when seeded in 24 combinations and rates with ryegrass. The figures are means of 3 replicated plots

RATE OF SEEDING HARDING-GRASS	RATE OF SEEDING RYEGRASS						
	0	3	6	9	12	15	Av.
1	302	12	8	10	7	2	57
2	420	33	11	11	11	7	82
3	627	29	34	17	34	14	126
4	776	166	40	16	39	17	176
Av.	531	125	23	14	23	10	

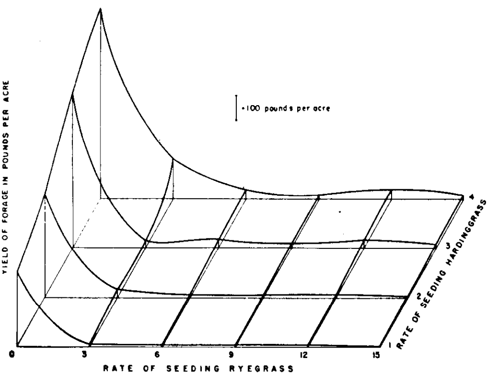

FIGURE 4. The same data as in Table 3 showing relative yields of hardinggrass with increasing rates of seeding of hardinggrass (front to back) and increasing rates of seeding of ryegrass (left to right).

Number of plants

To determine whether competition of the ryegrass plants tends to kill the hardinggrass plants or merely reduce their size, number of hardinggrass plants and their average weights were recorded. Numbers of plants of hardinggrass were reduced by one half when three pounds of ryegrass were seeded with it, and by half again when another three pounds were added to the seeding rate. Additional increases did not reduce hardinggrass numbers significantly (Table 4).

Without competition from ryegrass, an average hardinggrass plant weighed 20.5 grams; competition from ryegrass,

TABLE 4

Average numbers of hardinggrass plants per 500 square feet for each combination. Means of 3 replicated plots

RATE OF SEEDING HARD-ING GRASS	RATE OF SEEDING RYEGRASS						
	0	3	6	9	12	15	Av.
1	233	54	62	102	46	21	86
2	380	138	108	85	72	144	154
3	494	101	180	111	192	87	194
4	510	549	135	155	123	165	270
Av.	404	210	121	113	108	104	

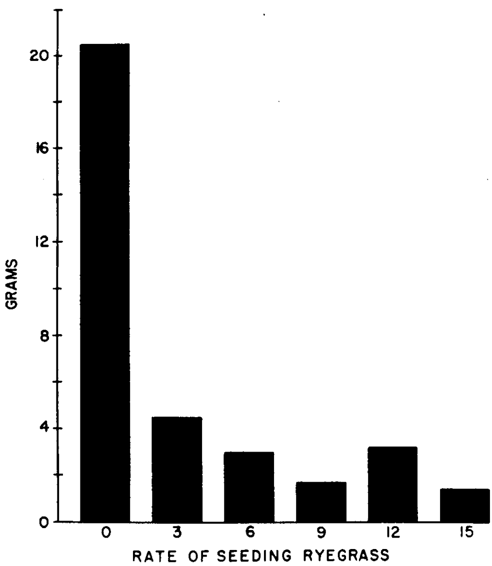

FIGURE 5. Average weights of individual hardinggrass plants when seeded alone and with five different rates of ryegrass.

even when seeded at the lowest rate (three pounds per acre), resulted in the production of hardinggrass plants averaging only 4.5 grams in weight (Fig. 5). Increasing the seeding rates of hardinggrass had no significant effect on the average weight of hardinggrass plants, thus indicating little or no competition between the individuals of that species alone.

Domestic Ryegrass—Tall Fescue

Because of the difficulty in distinguishing ryegrass from tall fescue plants in the seedling stage, data on germination were not obtained. For the same reason no density estimates were made to correspond to those obtained for the ryegrass-hardinggrass plots.

The yield data were very similar to those of the ryegrass-hardinggrass plots. The rate of seeding of tall fescue had no effect on yield of ryegrass. The yield of ryegrass was maximum at the six-pound per acre seeding rate. Competition between the ryegrass and tall fescue was severe enough, even at the three-pound per acre seeding rate of ryegrass, to depress the yield of tall fescue by 83 percent of that which occurred when no ryegrass was present.

Number of tall fescue plants corresponded closely with the rate of seeding of that species but varied inversely with the rate of seeding of ryegrass. Without competition from ryegrass, an average tall fescue plant weighed four grams. When seeded with three to 15 pounds of ryegrass, however, an average plant weighed 33 to 50 per cent less. Reduction in weight from ryegrass competition was less than with hardinggrass. Since weights of individual plants were not reduced by more than 50 percent from ryegrass competition, it can be assumed that the greater reductions in total yield of forage, mentioned above, were due largely to a loss of plant numbers.

Domestic Ryegrass—Smilo

The ryegrass-smilo plots were grazed by sheep and horses immediately after germination of the ryegrass and until the following May. The effect of the grazing was noticed chiefly on the ryegrass; therefore no density or yield data were obtained on this species. Emergence of smilo seedlings was delayed until January. This perennial made most of its top growth during late spring. Competition from ryegrass affected the yield of smilo in about the same manner as it did hardinggrass and tall fescue. Although little of the smilo had been grazed, it produced about one-fifth as much forage as did the other two perennial species. The low yields of smilo, in comparison with hardinggrass and tall fescue, were due to smaller and fewer plants. The late growth of this species seemed to be the chief factor in accounting for its low yield.

Discussion

In combinations of seedings involving annuals and perennials, the annuals have the advantage in competition because of earlier germination and faster growth. In the present study nearly all the ryegrass seedlings had emerged before any of the perennial grass seedlings had started. There was a lag of approximately three weeks for hardinggrass and seven weeks for smilo in time of seedling emergence after ryegrass had emerged. Presence of the already well established ryegrass may have retarded the germination of perennial grass seed or at least obstructed the emergence of some of the seedlings. During the early stages of development of both types of seedlings, there was sufficient moisture in the soil for plant growth. Yet, mortality of both perennial and ryegrass seedlings was noted at that time. If this mortality can be attributed to competition, then it is probable that factors other than water were causative.

Roots of annual ryegrass are faster

growing than those of the perennials but as yet little is known about the relative efficiency of the root systems in absorbing soil moisture. The earlier germination and faster growth of the annual is a definite and measurable disadvantage in perennial grass establishment. It results in crowding out a large number of perennial seedlings early in the season, and more later on. Later in the season it results in stunting the growth of many of the perennial plants whose roots are near the ryegrass.

The question as to whether the retarding effect of the ryegrass on the perennial grass during the first year of growth will be noticeable over a longer period of time must be answered before the results of this study can be used in recommending seeding rates.

Summary

In California, west of the Sierra Nevada Mountains, many acres of burned-over brushlands are reseeded to grasses and legumes each year. On the better soils several species of forage plants are well adapted for this purpose. Usually mixtures are seeded, a common one being varying amounts of ryegrass with legumes and perennial grasses.

A study was initiated to measure competition between domestic ryegrass and hardinggrass, tall fescue, and smilo. The first is an annual, the others are perennials. Information of this kind is essential for determining most effective combinations to reseed. This study covers only results of the first year after planting.

The experimental design used was a split-plot factorial with perennials seeded at four levels and the annual at six; the resulting 24 combinations were replicated three times for each of the three perennials. The following specific questions which the experiment was designed to answer are given with the results:

1. *What is the relation between the rate of seeding of each species and its density and yield?* Foliar density of ryegrass was greater with each increase in seeding rate up to 9 pounds per acre and then became less; forage yield was greater with each increase in seeding rate up to 6 pounds per acre only. Density and yield of perennials increased linearly with each increase in their seeding rate.

2. *What is the relation between rate of seeding of ryegrass and the yield of the perennials when seeded in combination with the ryegrass?* Forage yield of the perennial grasses was lower for each increment in seeding rate of ryegrass. The regression of perennial grass yield on ryegrass seeding rate was significantly quadratic at the 99 percent level.

3. *Is the effect of the different rates of seeding of ryegrass on the yield of the perennials greater or less than the effect of different rates of seeding of the perennials?* The effects of increased seeding rates of ryegrass largely masked the effects of increasing seeding rates of the perennial. From these studies it appears that the establishment of a good stand of hardinggrass, tall fescue, or smilo depends much more on the rate of seeding of a competing annual grass such as ryegrass than on the rate of seeding of the perennial itself.

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