Seeding Rate-Cover Relationships of Annual Ryegrass Seeded on Burned Brushlands

VASILIOS PAPANASTASIS AND HAROLD H. BISWELL

Highlight: *The relationship between seeding rate and cover of reseeded annual ryegrass (*Lolium multiflorum *Lam.) was studied for 3 years on a burned brushland near Berkeley, California. Five seeding rates were compared: 6, 11, 22, 34, and 45 kg/ha. During the first winter the percentages of cover from the high seeding rates were greater than those from the lower rates; however, the differences were eliminated in the spring as a result of more tillering in the areas of low seeding rates. Percentages of cover declined in the second and third years even though seed supplies were, respectively, 32-fold and double that of the first year. It is suggested that high rates of seeding be used after wildfires, where the objective is to have a good cover to protect bare soil against erosion during the winter months.*

Annual ryegrass (*Lolium multiflorum* Lam.) is widely used for seeding burned brushlands in California. The California Division of Forestry, for example, has seeded this species on 226,800 ha of wildburns on private and state lands between 1956 and 1971 (Anonymous, 1957 through 1971). It has also been used in stabilizing road cutbanks along highways and forest roads (Bowmer and McCully, 1968; Jackman and Stoneman, 1972).

The ability of annual ryegrass to grow in winter and early spring, together with the vigor of seedlings, high tillering capacity, and prolific root system makes it a desirable species for groundcover during the first growing season after fire—the most critical for protection against soil erosion. A good cover of ryegrass depends in part on the amount of seed planted, provided the first storms are not so severe as to wash the seeds and ash down the slopes (Love, 1970). The higher seeding rate results in a denser crop, higher cover, and better protection for the bare soil. The relationship does not hold altogether, however, because of the tillering capacity of annual ryegrass.

No information exists about the optimum seeding rate of annual ryegrass for this early critical period. Nor is it known how the seeding rate is associated with the behavior of ryegrass over time.

The seeding rates employed by the California Division of Forestry have ranged from 7 to 9 kg/ha, with a few as high as 22 kg/ha (Anonymous, 1957 through 1971); however, no background information is given as to why these rates were selected. Schultz and Biswell (1952) found that 10 kg/ha gave the highest cover and 7 kg/ha the highest forage yield of annual ryegrass when combined in mixtures with perennials in the Sierra foothills in California. On the other hand, high seeding rates have been suggested for erosion control of road banks. For example, Jackman and Stoneman (1972) recommended 56 kg/ha of annual ryegrass and urea fertilizer for road banks on the Jackson State Forest in the redwood region of California, and McCully and Bowmer (1969) suggested up to 17 kg/ha of annual ryegrass seeded with 13 kg/ha of bermudagrass (*Cynodon dactylon*) for the roadsides of eastern Texas.

The seeding rate determines not only the cover (percentage groundcover) but also the density (number of plants per unit area) and subsequently the herbage and seed production. Broughman (1954) reported increased total herbage and increased ryegrass with increase in seeding rate from 0 to 67 kg/ha of ryegrass seeded with clovers in New Zealand. On the other hand, low seeding rates, less than 15 kg/ha, are suggested for all grasses for seed production (Evans, 1959; Griffiths and Roberts, 1969).

The objective of this study was to evaluate the seeding

Authors are PhD graduate student in range management, and professor of forestry, emeritus, University of California, Berkeley. Papanastasis is now at the Northern Greece Forest Research Center, Loutra of Thermis, Thesalonika, Greece.

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rate-cover relationships of annual ryegrass seeded on a burned brushland and describe its behavior over a 3-year period.

Materials and Methods

In November, 1970, a factorial experiment in a randomized-block design (Hicks, 1964) was established on a wildfire-burned brushland in the hills near Berkeley, Calif. The fire occurred in September, 1970, and swept through brush vegetation, mainly coyote brush (*Baccharis pilularis*). Factors of the experiment were seeding rate and aspect. The seeding rates used were 5.6, 11.2, 22.4, 33.6, and 44.8 kg/ha (5, 10, 20, 30, and 40 lb/acre), and are reported here as 6, 11, 22, 34, and 45 kg/ha. The aspects were northwest and south exposures. The rates were completely randomized in blocks and were replicated once in each aspect, giving a total of 20 plots, 2 × 2 meters each.

Density and cover were measured for three growing seasons. In the first, measurements were taken every 2 weeks; in the second and third seasons, density was measured at the beginning of each season, soon after germination, and cover was measured at the end of each season.

Density was measured at the first sampling date (December 31, 1970) by taking 10 one-square-decimeter quadrats for one-square-meter plot and counting the number of seedlings. This technique was meaningless in the subsequent dates, however, because the seedlings had started to tiller. For this reason, the sampling was continued by counting the number of tillers per individual plant. In the second and third years, density was measured by using the square-inch quadrat (Heady, 1958) and taking four quadrats per plot.

Throughout the experiment, cover was measured with the point frame, by taking 50 points per plot. Analysis of variance was used to test the hypotheses of homogeneity of means. Whenever necessary, a multiple-comparisons test was run by means of the studentized range (*Q*-test). All tests were done at the 0.05 level of significance.

Results

Density

Density at the beginning of the season for the first year is given in Table 1. The number of seedlings per square meter ranged from 180 to 2,070, respectively, for the lowest and highest rates of seeding. Analysis of variance gave significant differences among seeding rates but not between aspects. *Q*-tests showed significant differences among all seeding rates except those between 6 and 11, and 11 and 22 kg/ha, which means that significantly different populations of seedlings came from the 22 kg/ha rate and above.

Taking into account that 366 seeds were found in a gram, and that an average 2.38 gm/m^2 were planted, a total of 873 seeds was planted per square meter. That number, compared with the mean total seedlings (870) shows germination of almost 100%.

In the later dates of the first growing season, the number of tillers per plant were counted. The means per seeding rate, aspect, and date averaged over the north and south aspects are shown in Figure 1. The number of tillers per plant ranged from one, on the first date, to 43 on the latest. Tillering was higher and faster with the low rates and on the south aspect than with the high rates on the north aspect. The seedlings at all seeding rates started as individual plants, i.e., without tillers, but by the middle of January, significant differences were apparent among rates and also between aspects.

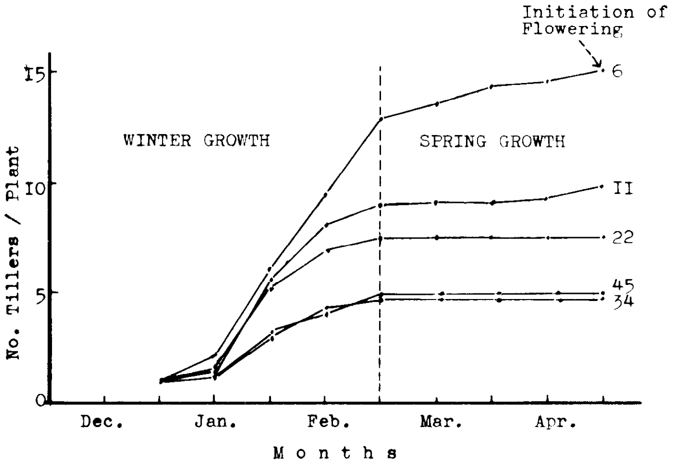

Fig. 1. *Time change in number of tillers per plant for the five seeding rates (kg/ha).*

The significant differences in the number of tillers per plant among the seeding rates were maintained until the end of the season. *Q*-tests, however, showed that the differences were of different origins as the season progressed. Tillering at the 6 kg/ha rate remained significantly different from all other rates at all nine sampling dates with the exception, at times, of rate 11. The 11 kg/ha rate continuously maintained significant differences with rates 34 and 45. The significant differences among the remaining dates, however, disappeared with the beginning of the rapid spring growth, as did the differences between the two aspects.

The second growing season started with a tremendous number of seedlings (Table 1—Dec. 30, 1971). The count was 28,400 seedlings per square meter, as compared with 870 seedlings in the first year. By the same logic as that applied to the first year, and assuming 366 seeds per gram, with 100% germination, this high population of seedlings must have come from a seeding rate of 776 kg/ha. This shows how large the seed yield was at the end of the first season, and the actual amount was even greater but seeds were lost through predation or other causes during the dormant period. Analysis of variance showed no significant differences among seeding rates this second year, but between aspects more seedlings were found on the south than on the north.

The third growing season showed a tremendous drop in the number of seedlings (1,810 per square meter) compared with the year before (Table 1—Dec., 1972). Again using the same logic as before we find the seeding rate must have been at least 49 kg/ha. Finally, no significant differences were obtained among rates or aspects.

Table 1. Means of ryegrass density (thousands seedlings/m^2) at the beginning of the season over a 3-year period.

	Seeding rate (kg/ha)					Aspect	
Date	6	11	22	34	45	North	South
Dec. 31, 1970	0.21	0.45	0.68	1.30	1.72	0.85	0.88
Dec. 30, 1971	30.04	30.61	26.54	27.42	27.31	19.61	37.23
Dec. 29, 1972	1.05	2.62	1.05	1.55	2.81	2.09	1.55

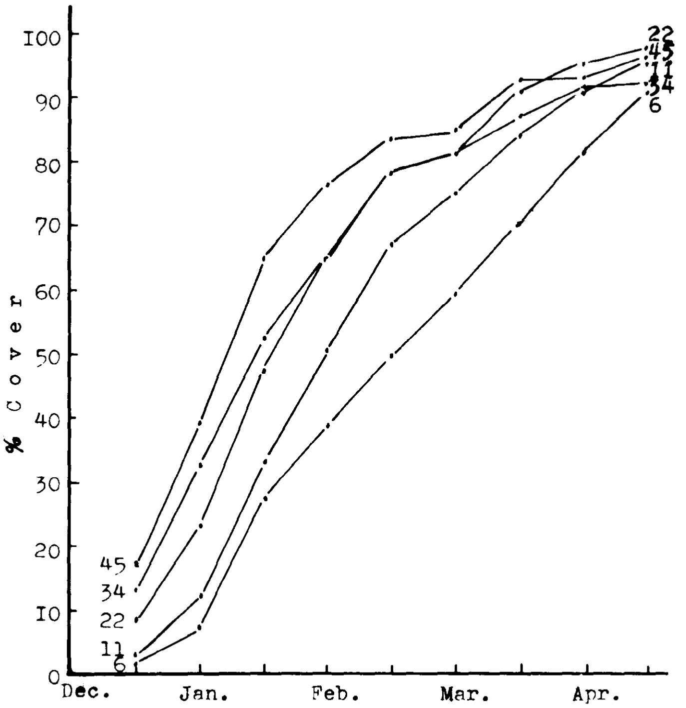

Fig. 2. *Time change of ryegrass cover for the five seeding rates (kg/ha).*

Cover

The results of ryegrass cover for the first growing season are shown in Figure 2. Because of the different density, the five seeding rates started with a different cover at the beginning of the season, the low rates having less cover than the high ones. The cover immediately began to increase rapidly, but with a different speed for each seeding rate, until the middle of March, the last date to show significant differences among rates.

The high rates of 22, 34, and 45 kg/ha maintained significant differences in cover from that of rate 6 throughout the winter period (until the end of February). Rate 11 differed significantly from rate 34 by the middle of January, and from rate 45 by the middle of February.

For the aspects, the original significant differences disappeared in February, but reappeared in March.

The ryegrass cover at the end of the second growing season is shown in Table 2 (May 21, 1972). Compared with the first season (April 24, 1971) the cover had decreased tremendously from 94.3% to 3.0% on the average. No significant differences were found among rates nor between aspects.

Rainfall and Temperatures

Weather data were taken from a nearby station located on the Berkeley campus.

For the months September to May, the precipitation varied greatly in the 3 years. It was about normal the first year (575 mm); down to 311 mm in the second year, which is 239 mm below normal; and 939 mm in the third season, which is 389 mm above normal. Judging from the amount of rainfall, the growing season started in late October the first year, mid-November the second year, and early October the third year.

The distribution of rainfall varied. November had the highest rain in the first year, December in the second, and January in the third. In the first year, about 70% of the total rainfall for the 9 months from September to May fell in the 2 months of November and December. Those same months received about 50% of the rainfall in the second year and less than 30% in the third year.

Temperatures did not differ very much among years although the third year was colder than the other two in the winter months.

Discussion

The relationships between density and herbage yield and density and seed yield have been extensively studied, but are still not fully understood (Donald, 1963). Studies of the relationship between density and leaf area index have also been made, but the literature gives little information about the relationship between density and cover.This is not surprising, because all the above-mentioned studies have been carried out in agronomic environments where cover, an important ecological attribute, has no practical meaning.

The following points have come out of this study:

1. The number of seedlings emerged after seeding in the first year was linearly related to the number of seeds planted. Elsewhere (Papanastasis, 1973), this linear regression is reported to be: $\hat{Y} = 40.11 + 43.74\,X$ with X being the seeding rate (kg/ha) and $\hat{Y}$ the number of seedlings per square meter, and with a correlation coefficient of 0.96. The same was found by Brougham (1954) with the short-rotation ryegrass (*Lolium perenne* × *L. multiflorum*) at even higher seeding rates (up to 67 kg/ha).

2. Tillering started earlier and was faster with the low seeding rates (6, 11 kg/ha) than with the high ones (22, 34, 45 kg/ha). As the period of rapid spring growth (in terms of leaf expansion and shoot elongation) approached, the plants from low seeding rates continued tillering, but at a slower rate until the flowering stage; while those from the high seeding rates kept their numbers constant for the rest of the season (Fig. 1). The high rate of tillering in the plants from the low rates of seeding can be attributed to more available light. On the other hand, light might have been limited right after germination in the high-density seedings (Donald, 1963). Furthermore, the higher rate of tillering in the winter period can be attributed to the low temperatures, which favor tiller production (Williams, 1970).

3. Cover followed a pattern similar to that of tiller production (Fig. 2). The low rates (6, 11) started with a lower cover than the high ones (34, 45), with rate 22 being intermediate. Rate 6 continued to produce less cover than rates 22, 34, and 45 until the end of the winter growth, while

Table 2. Means of ryegrass cover (%) at the end of the season for a 3-year period.

	Seeding rate (kg/ha)					Aspect	
Date	6	11	22	34	45	North	South
Apr. 24, 1971	90.5	95.0	97.5	92.5	96.0	100.0	88.6
May 21, 1972	4.5	4.0	3.5	1.0	2.0	2.4	3.6
May 13, 1973	11.0	19.5	20.5	23.0	24.0	22.5	16.6

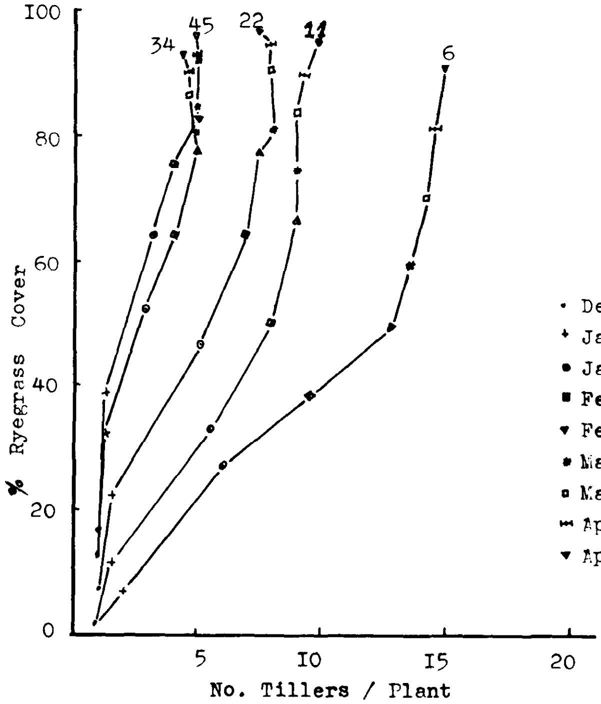

Fig. 3. *Relationship between number of tillers per plant and percent cover of ryegrass for the five seeding rates (kg/ha).*

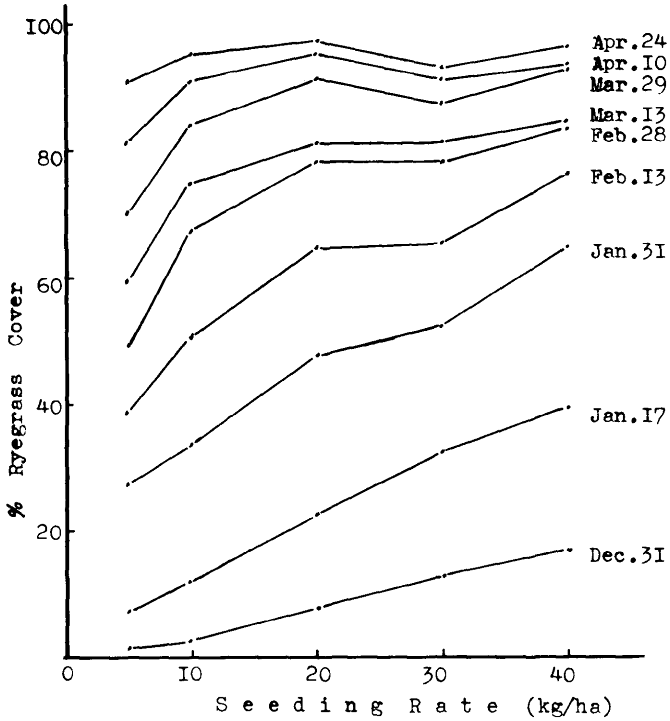

Fig. 5. *Relationship between seeding rate (kg/ha) and percent of cover of ryegrass.*

rate 11 made the same cover with the high rates 1 month earlier than did rate 6.

4. While cover depends on the number of tillers, their size or vegetative stage is important, too. Figure 3 shows the relationship between number of tillers per plant and cover. It is apparent that the same cover was reached under the different seeding rates at different times despite the different rates of tillering. This clearly shows that the number of plants (density) is much more important for a higher cover than is the number of tillers at least for the early part of the growing season.

5. It is well documented that the herbage yield of a grass crop increases as density increases, and that maximum yield is reached at moderate densities and remains constant thereafter at a value determined by environmental factors. On the other hand, the maximum seed yield is also reached at moderate densities, but yield declines as density further increases (Donald, 1963). The results of this experiment show that tillering is independent of density at the emergence stage, and decreases linearly as density increases during the slow winter growth; the relationship then becomes exponential with the initiation of rapid spring growth (Fig. 4). The cover increases linearly as density increases during winter growth, but the relationship becomes asymptotic during the fast-growth period, and reaches a ceiling value (not more than 100%) determined by the environment (Fig. 5).

6. Figure 6 shows the relationship between precipitation for the nine months, September to May, and density and cover for three growing seasons. It is apparent that: (a) no intimate relationship seems to hold between cover and amount of rainfall; (b) density at the beginning of the season was highest the second year and lowest the first; and (c) cover of ryegrass at the end of the season was highest in the first year and lowest in the second, thus showing a decline through time, although not linear.

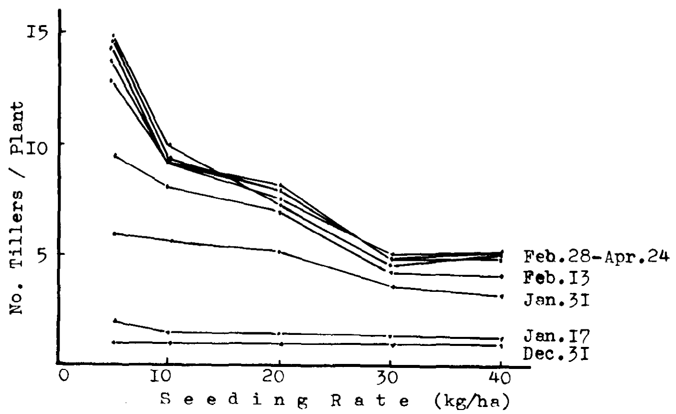

Fig. 4. *Relationship between seeding rate (kg/ha) and number of tillers per plant.*

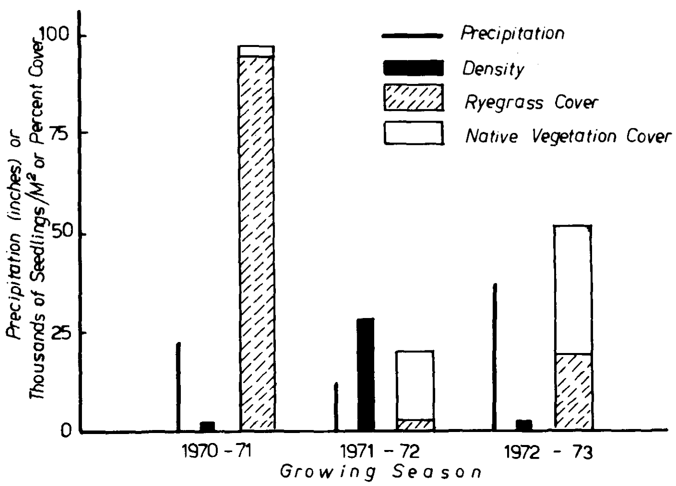

Fig. 6. *Time change in precipitation (inches), density (thousands of seedlings/m²) in the beginning of the season and percentage of ryegrass and native cover at the end of the season.*

Conclusions

The following conclusions may be drawn from this study:

1. Since cover is a function of seeding rate in the critical early winter months of the first year, high seedling rates (20 kg/ha or over) for soil erosion prevention are recommended.

2. Density in the beginning of the growing season has little to do with the cover achieved at the end of the season, the final result depending on the particular year involved.

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