Factors Involved in the Decline of Annual Ryegrass Seeded on Burned Brushlands in California

VASILIOS PAPANASTASIS

Highlight: *The effect of amount of mulch, nitrogen fertilizer, and clipping frequency was studied on herbage and seed production of annual ryegrass (*Lolium multiflorum *Lam.) seeded on a burned brushland in California. The experiment was continued for 2 years but, in the second year, actual grazing by meadow mice (*Microtus californicus*) was substituted for the clipping treatment. Available nitrogen in the soil was found deficient in both years but the deficiency was more pronounced in the relatively dry year. Meadow mice reduced herbage and seed yields significantly in the second year. It is concluded that the decline of annual ryegrass in burned brushlands is associated with a corresponding decline through immobilization of available soil nitrogen released by brush burning.*

Annual ryegrass (*Lolium multiflorum* Lam.) is extensively used for emergency revegetation of burned brushlands in California. Its easy establishment, vigorous seedlings, and prolific root system, as well as its cheap and abundant seed, makes it a good choice for seeding burned brushlands where protection of the bare soil from erosion is urgently needed. Although it provides a satisfactory foliage cover in the first or second growing season, it declines in abundance thereafter to drop out partially or completely in a period of 3 to 5 years after the seeding (Anonymous, 1957 through 1971; McKell et al., 1965; Papanastasis, 1973).

Several factors seem to be involved in this decline of annual ryegrass. McKell et al. (1969) found that ryegrass mulch retards the establishment and growth of other species but they could not explain whether that was a mechanical or chemical effect. Based mainly on laboratory experiments. Naqvi (1969) attributed this interference primarily to chemical inhibition, implying also the possibility of self-interference of annual ryegrass itself. However, Bowmer and McCully (1968) failed to find any active inhibitors in annual ryegrass plants in the field.

Soil fertility is another factor. Annual ryegrass requires fertile sites and it responds readily to nitrogenous fertilizers (Hunt, 1962; Jones et al., 1970). It also responds to phosphorus applications when the phosphorus level in the soil is low (Lawas and Goodman, 1970). Moreover, nitrogen fertilizer is recommended for increased seed production (Evans, 1960).

At the time of the research, the author was graduate student at the Department of Forestry and Conservation, University of California, Berkeley. At present he is at the North Greece Forest Research Center, Vasilika, Thessaloniki, Greece.

Manuscript received May 29, 1975.

Brushland soils of California were found to be deficient in nitrogen and phosphorus (Vlamis et al., 1954, 1959). However, brush burning releases a measurable amount of available nitrogen, phosphorus, and sulfur to the soil (Vlamis and Gowans, 1961). Apparently the nitrogen declines rather rapidly since Vlamis et al. (1955) found that a 2-year-old burn contained less available nitrogen than a 1-year-old burn.

Grazing by livestock is not normally practiced in areas burned and seeded for soil protection, and there is no evidence that early spring grazing by deer can be much of a problem. However, annual ryegrass is a preferred food for the small rodents. Batzli and Pitelka (1971) found that meadow mice (*Microtus californicus*) preferred annual ryegrass to several other annual grasses within the California annual type. Moreover, Cook (1959) recorded a sizeable population of small rodents invading a burned brushland from adjacent areas in California.

The objective of this research was to study the effect of amount of mulch, nitrogen fertilizer, clipping frequency, and meadow mice on herbage and seed production of annual ryegrass over a 2-year period and to relate this effect to the problem of annual ryegrass decline on burned brushlands.

The study area was located near Berkeley, Calif. The vegetation was made up mainly of coyote brush (*Baccharis pilularis*) which was burned by a wildfire in September, 1970. Immediately after the fire the area was seeded by helicopter with 22 kg/ha of annual ryegrass.

Materials and Methods

Prolific growth of annual ryegrass in the first growing season resulted in a thick layer of dead organic matter (mulch) in the summer of 1971. At that time a split-plot factorial experimental design (Hicks, 1964) was established on the burned and seeded brushland.

The whole plots were amount of mulch (0, 3,000, and 6,000 kg/ha) and nitrogen fertilizer (0, 56, and 112 kg/ha); the split plots were clipping frequency set up at three levels: no clipping (0), clipping once (1), and clipping twice (2). The resulting 27 combinations (plots)—2 × 2 meters squared—were randomly replicated three times over an area of about 1/5 hectare on a northwest facing slope.

The experiment was continued for 2 years. In the second year, however, a rodent control treatment was substituted for the clipping treatment. Rodents were either normally present or completely excluded (Fig. 1). The two rodent treatments were applied on the plots clipped once and twice respectively, which were found with no significant differences in the first year (see below); the unclipped plots were ignored. This

Fig. 1. *The experiment with the mice exclosures.*

reduced the treatment combinations to 18, replicated three times (Total 54 plots).

To save time and cost in building the fences, the total plots were reduced by half (27) by means of the fractional replication technique (Hicks, 1964). The fraction used gave the main effects of the three factors and the location (replication) treatment clear of the first order interactions; besides, the first order interactions among the three factors were independent; but the ones with the location effect were dependent and were assumed to be zero to make possible the analysis of variance (Hicks, 1964; Hahn and Shapiro, 1966).

In both years, the mulch treatments were applied at the end of the summer. Different amounts of the dead ryegrass vegetation were removed by clipping or added on the plots until the desired levels were achieved. A field scale was used to check the weights.

Nitrogen was applied in both years as urea before the fall rains. A basic application of 560 kg/ha superphosphate fertilizer was given to all plots within the nitrogen treatment.

Plots were clipped both early, at the end of February just before initiation of the rapid spring growth, and late, at the end of March before the flowering growth stage. Treatment 1 consisted of only the late clipping; treatment 2 involved clipping both early and late. Clipping was done to a height of 3–4 cm.

The mice exclosures were built with 8-mm wire mesh sunk 25–30 cm into the soil. The fences extended 55 cm above the ground surface and had 15 cm wide flanges bent outwards (Fig. 1).

Herbage and seed production were measured at the end of the season by taking two quadrats of 929 square centimeters each (one square foot) per plot. Seeds were separated from the stalks by rubbing and putting them through a clipper cleaner.

Impact of small rodents on the plots in the first year was minimized by systematic snap-trapping and poisoning. This was continued for pocket gophers the second year. Mice, however, were not removed in the second year (except from within the exclosures) and their population was measured four items during the year using the capture-release method. Mice were trapped with Sherman live traps, marked by clipping their toes, and the population size estimated by the Petersen-Lincoln Index (Hayne, 1949).

Results

The results of the various treatments on herbage and seed production are given in Figures 2–5 for both 1972 and 1973. The data were subjected to analysis of variance. Before running the experiment, contrasts were decided upon between the first and second and between the second and third levels of mulch, N fertilizer, and clipping frequency. These were tested with the F-statistic. All hypotheses were tested at the 0.05 level of significance (Hicks, 1964).

First Year (1972)

Mulch up to 3,000 kg/ha did not significantly reduce herbage and seed yields. However, 6,000 kg/ha of mulch significantly reduced herbage production compared to the zero and middle levels, and reduced seed production compared to the zero level.

Nitrogen fertilizer increased herbage production significantly. A 57% increase was obtained by adding 56 kg/ha, and a 106% increase was obtained by adding 112 kg/ha. The effects on seed production were similar, i.e., 50 and 100% increase respectively.

Clipping during the rapid growth period (end of March) reduced significantly both herbage (55%) and seed yield (28%); no significant differences were found between clippings once and twice.

Interactions between mulch and N fertilizer, mulch and clipping were found to be significant for the herbage but not for the seed yields (Fig. 2 and 3).

Second Year (1973)

Mulch had no significant effect on herbage and seed yield this year.

Nitrogen fertilizer increased herbage production significantly but it did not make any difference whether 56 or

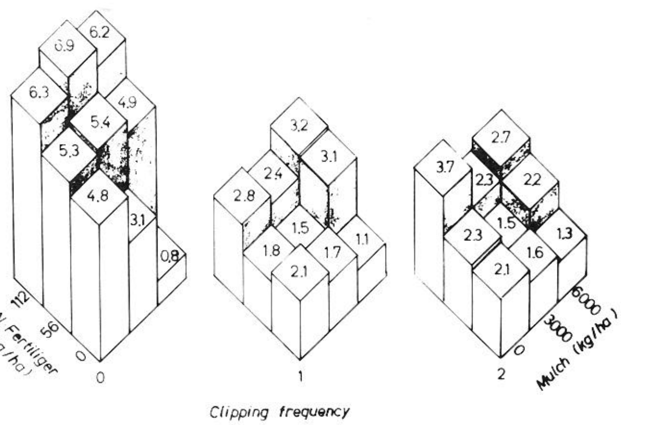

Fig. 2. *Herbage production in tons/hectare under three levels of fertilization, mulching, and clipping in 1972.*

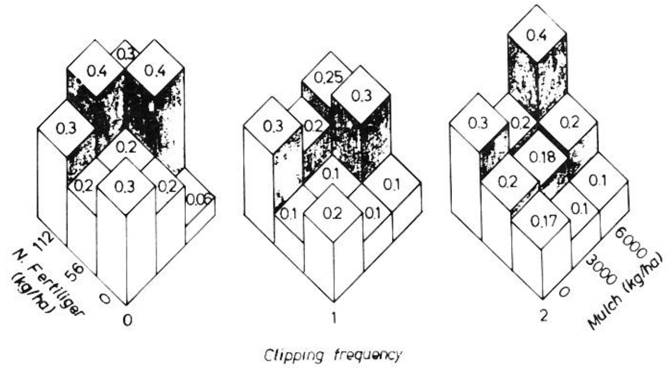

Fig. 3. *Seed production in tons/hectare in 1972 (treatments as in Figure 2).*

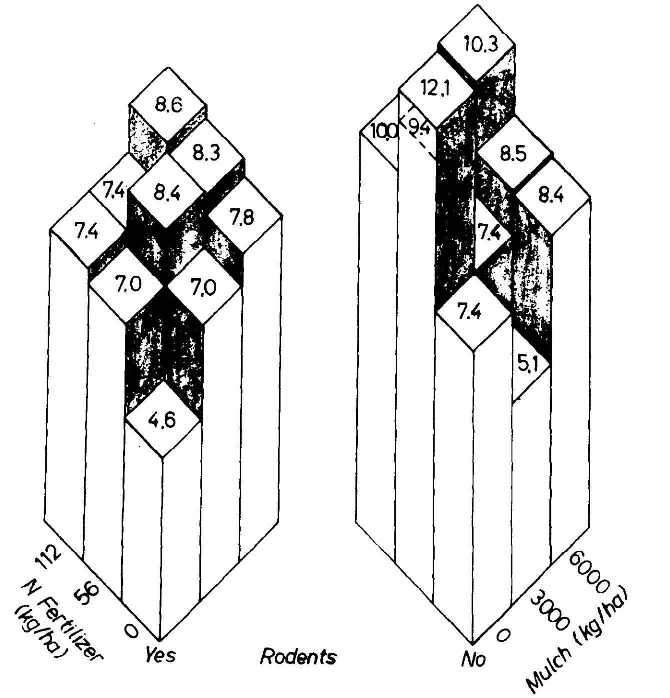

Fig. 4. *Herbage production in tons/hectare under three levels of fertilization and mulching and two rodent treatments in 1973.*

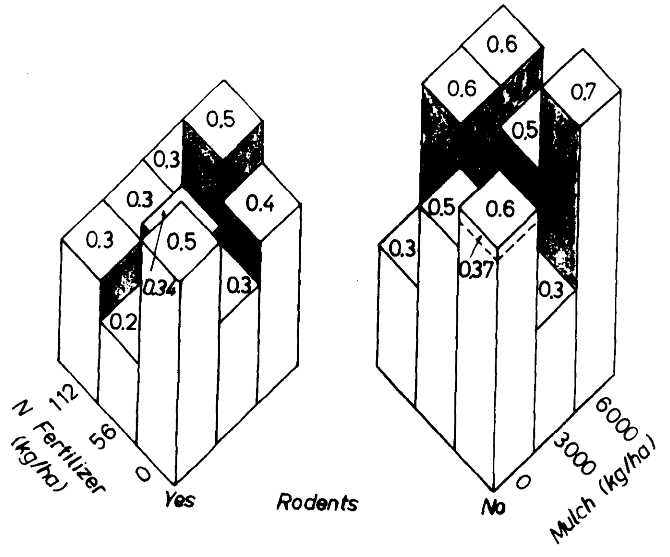

Fig. 5. *Seed production in tons/hectare in 1973 (treatments as in Figure 4).*

112 kg/ha of it were applied. Fertilization had no effect on seed yields.

Herbage production was found to be 18% and seed yield 67% higher in the rodent exclosures than where mice had full access to the vegetation.

Finally, interactions between any two of the factors–mulch, N fertilizer, and rodents–were found insignificant for both herbage and seed production (Fig. 4 and 5).

The population of mice on this study site was 300 individuals/ha in November; of those, 220 were meadow mice and the remaining harvest mice (*Reithrodontomis megalotis*). In January, the total population declined to 253 mice/ha; of those 200 were meadow mice and the rest harvest mice. In March, the total population was further decreased to the level of 153 mice/ha, including 120 meadow mice. Finally in May, the harvest mice disappeared, but the meadow mice increased to 420/ha.

Discussion

The effect of the factors studied on annual ryegrass was not consistent in the 2 years. This is apparently due to different amounts of rainfall in the 2 years; for the months September to May, the rainfall was 311 mm in the first year and 939 in the second. Since the normal precipitation on the area for these months is about 500 mm (Papanastasis, 1973), the first year was considerably drier than the second.

The favorability in rainfall of the year 1973 raised its herbage yield to 7.4 tons/ha (exclosed, unmulched, and unfertilized plots–Fig. 4) as compared to 4.8 tons/ha of the year 1972 (unclipped, unmulched, and unfertilized plots–Fig. 2). However, both years had lower yields than 1971, the year which followed the fire and seeding; in that year, herbage production was 10.0 tons/ha and rainfall about normal (575 mm) (Papanastasis, 1973). These data show that there was a decline in herbage production with time, which would have, apparently, been linear if precipitation had remained the same in the years 1972 and 1973.

The linear response of herbage and seed yields to nitrogen fertilizer in the first year indicates that there was a nitrogen deficiency in the soil. A deficiency was also present in the second year, but it was not so pronounced, perhaps because improved soil moisture might have led to a higher mineralization rate of some of the organic nitrogen (Black, 1968). If soil moisture had remained the same, one would expect the soils to be more deficient in nitrogen the second year than in the first because the available nitrogen released by brush burning declines with time (Vlamis et al., 1955; Vlamis and Gowans, 1961).

The lack of any different effect of the top rate of nitrogen fertilizer on herbage compared with the middle one in the second year can be attributed to losses by leaching in the beginning of the season before the plants had grown enough to take all the extra nitrogen of the top rate.

Mulch is well known for its ameliorating effects. It stabilizes soil temperature and soil moisture. The latter can be increased through control of the infiltration rate, evaporation, and runoff. Most investigators agree that herbage yield is favored by mulch up to a point but that excessive mulch accumulation decreases both herbage yield and the number and size of seed stalks (Weaver and Rowland, 1952; Tomanek, 1969). Heady (1956) found that herbage yields in the California annual type increased with up to 2,690 kg/ha of mulch.

The upper point in my study was beyond the 6,000 kg/ha in the second year, since no significant effect of mulch was found on herbage and seed yields. However, the upper point was apparently somewhere between 3,000 and 6,000 kg/ha the first year of the study.

The depressing effect of 6,000 kg/ha of mulch in the first year suggests that it created unfavorable conditions to plants possibly by intercepting the limited precipitation and thus restricting the amount of available moisture and uptake of nutrients from the soil. However, nitrogen fertilizer counteracted the mulch effect (significant interaction); apparently the greater amount of organic matter in the soil under low rainfall created conditions favorable for the immobilization of the mineral nitrogen (Black, 1968). This shows again the importance of soil nitrogen for the growth of annual ryegrass and questions the inhibitory effects of its dead material as supported by other investigators (McKell et al., 1969; Nagvi, 1969).

Clipping during the fast growth of annual ryegrass reduced herbage and seed production, possibly by damaging the elevated shoot apex of most plants and preventing regrowth. However, Figures 2 and 3 indicate that fertilization with nitrogen tended to counteract the depressing effects of clipping and that was pronounced on the mulched plots. Therefore, one would expect higher rates of nitrogen and mulch to reach the production level of the unclipped plots. This suggests that lack of sufficient nitrogen is the most plausible explanation for the failure of the clipped plants to recover.

Grazing is not so severe as clipping. In the second year, however, grazing by mice reduced significantly both herbage and seed yields. It follows that the extent of the effect of mice on annual ryegrass depends on their population size; the higher their population the greater their grazing impact. On the other hand, since mice dispersion depends on cover and food provided by annual ryegrass, a good growth of the latter is a prerequisite for the growth of the former (Papanastasis, 1973).

Of the two mouse species recorded, meadow mouse is primarily a grass eater, while the harvest mouse is mainly a seed eater (Cook, 1959; Batzli and Pitelka, 1971). Therefore, the reduction of herbage in this study was attributed to the grazing effect of meadow mice, which constituted, also, the bulk of the total population.

The exclosure data are confounded with the micro-habitat effect of fences. Heady (1957) studied the effect of cages on yields in the California annual type; he found that the growth was significantly higher inside the fences in the winter, but the differences disappeared in the spring. The cages used in this study had six-fold denser mesh than those used by Heady but they had open tops. Therefore the evidence is that the fences did not affect the growth of annual ryegrass.

It is evident from this study that plots with more herbage have higher seed yields, suggesting the importance of a good growth of annual ryegrass for a high seed production. High seed yield results in establishment of good stands of annual ryegrass in burns (Papanastasis, 1973).

Conclusions

Annual ryegrass has a high demand of soil nitrogen to grow. This nitrogen is available in burned brushlands in the year(s) following the fire because it is released in the brush burning process. However, in the later years most of this nitrogen is immobilized by the accumulation of ryegrass mulch, thus depriving the new crops of annual ryegrass of sufficient soil nitrogen. Therefore, the decline in abundance with time of annual ryegrass in burned brushlands in California is associated with a corresponding decline through immobilization of available soil nitrogen released by brush burning.

Meadow mice can hasten the deterioration of annual ryegrass stands through grazing, but the extent of their impact depends on the size of their population.

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