efficiency for picking ground fruit and for picking ladder fruit can then be shown (graph 4). This simplifies comparison of the tasks and points out that the significant benefit of picking ground fruit over ladder fruit was in the efficiency of activity rather than in the level of energy input (graphs 1 and 2). Picking ground fruit was 25% more efficient than general picking. Ladder fruit picking was only 7% less efficient than general picking.

When modified tasks or developed devices are to be evaluated on the basis of efficiency, proper consideration must be given to the methods which demand high energy input—and may also afford an opportunity for proportionate productivity analysis. This cannot be done if one evaluates only the rate of energy input, or only the rate of production. The results reported here do not reveal anything contrary to what might be expected by a person with experience in citrus picking. The results do, however, provide a method and a quantitative base with which to compare advantages of proposed alterations in equipment and materials, management practices, tree structure, and fruit-bearing characteristics.

Cletus E. Schertz was Assistant Professor and Assistant Agricultural Engineer, Department of Agricultural Engineering, University of California, Davis, and is now Associate Professor, Department of Agricultural Engineering, University of Minnesota, St. Paul, Minnesota. *Assistance with this study was also obtained from the personnel of Central Valley Citrus & Packing Co., Orange Cove Citrus Ass'n, and Rancho Sespe. Juan Castillo, Ramino Rodriguez, Pete Carrillo, and Eliseo Vasguez were the pickers who cooperated during the study.*

SUMMARY

1. Pickers are 25% more efficient when picking ground fruit than during general picking.
2. Ladder fruit picking is not considered appreciably less efficient than general picking.
3. Ladder carry and setting require nearly two times the energy per unit of time that general picking requires.
4. The equipment for respiration calorimetry encumbers the subject.
5. There is need for a satisfactory calibration of energy expenditure with heart function or other body function *that can provide data easily,* without encumbering the subject.

Forage and Protein By Subclover-grass Nitrogen-fertilized California

Range grass areas including stands of subclover produced forage yields equal to those from nitrogen-fertilized annual grasslands in a moisture-deficient year in northern California, and more forage was produced in a moisture-adequate year, according to this study. Stands of subclover and grass produced forage yields equal to those from California annual-type grasslands fertilized with 45 to 90 kg of nitrogen (N) per hectare (45 kgN/ha = 40 lb/acre), in a moisture-deficient year (when rains began and ended in March). In a moisture-adequate year (with rains commencing in early October and ending in May), subclover-grass stands produced more forage than did resident grasslands fertilized with 179 kg N per ha. Nitrogen fertilization was found to contribute most to forage production during the winter period. Second- and third-year stands of subclover also showed production increases early in the season, but made the greatest gains in April and May.

MILTON B. JONES

ANNUAL-TYPE GRASSLANDS occupy extensive areas in California. These areas are characterized by a Mediterranean-type climate which is wet during the cool period of the year and dry during the summer months. These grasslands are designated as annual grasslands because winter annual species are the dominant cover. Hardinggrass, *Phalaris tuberosa,* a perennial, has been successfully established in some areas, but even in these areas annual species are generally dominant. A factor which limits production on most of these grasslands is soil nitrogen (N). There are two ways to increase N levels—by fertilization, and by establishing legumes.

Studies

Many studies have been made on the use of commercial N on annual grasslands in California. The effects of increasing rates of N, and of time of application, have been studied on small, ungrazed plots, and extensive work has been done with animals to evaluate the economics of N fertilization. Conclusions were that whether N fertilization is profitable on annual grassland depends upon management, prices, soil type, temperature, and amount and distribution of rainfall. Best results were observed on well-drained annual ranges where the seasonal rainfall was 15 to 25 inches. The price of commercial N has been very favorable in recent years, and its use has been widespread, even in areas of the state which are climatically well adapted for the growth of subclover.

Contribution

The contribution of self-reseeding annual legumes in increasing forage and N production on annual-type grasslands is well recognized. It has been estimated that from 45 to 60 lbs N per acre may be produced each year by annual legumes in California. Subclover, *Trifolium subterraneum* L., pastures in a Mediterranean-type climate at Crookwell, New South Wales, Australia, have reportedly added an average of 42.5 lbs of soil nitrogen per acre each year for periods up to 26 years. Yields have been reported from subclover plots in the north coast region of California of about 13,000 lbs of forage per acre,

Production and Grasslands

which compares very favorably with yields from plots in the same area that received heavy applications of nitrogen.

There has been a lack of precise information as to the actual value of N fertilization compared with the establishment of subclover-grass pastures, in areas climatically suitable for the growth of subclover. The objective of the work reported in this paper was to compare forage and protein production and N uptake of a subclover-grass association with annual-type grasslands fertilized with varying rates of N—and to do this under three different management treatments at two locations.

Three-year study

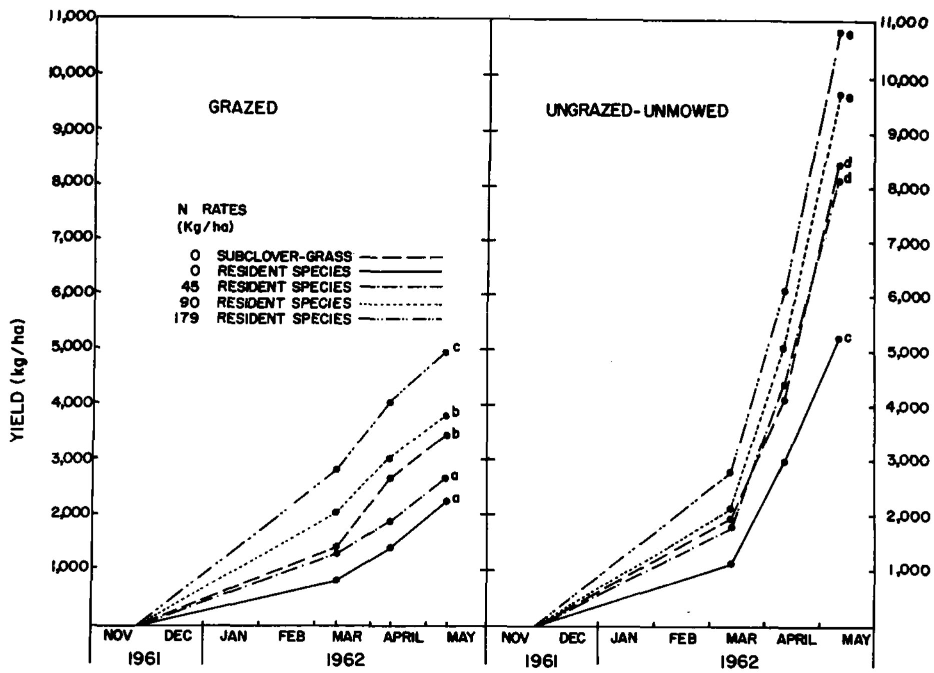
This three-year study was made on two soils—Sutherlin loam (annual species only) and Willits loam (annual species plus hardinggrass) at the University of California's Hopland Field Station, Mendocino County. The resident species at the experimental sites consisted of annual grasses and broad-leaved herbs including native trifolium species. The term "resident species" is used to indicate plants growing on the sites naturally, but which may not be native. Most of the annual grassland species have invaded since the settlement of California by the Spanish. Both sites were fertilized uniformly with 1121 kg single superphosphate/ha in October 1960, and 560 kg single superphosphate/ha in October 1961 and 1962, to insure adequate supplies of phosphorus and sulfur.

There were three forage management main plot treatments divided into eight fertility, subplots, with four replications of the 24 treatments at each of two sites. The three management treatments included (1) grazing, (2) mowing, and (3) natural condition (control). In the grazing treatment, eight or ten sheep were grazed for two or three days (at each sampling date) until the forage had been eaten down to a height of from 2 to 8cm. The sheep were kept in a corral during the night so that deposition of excretions on the plots would be minimized. Fecal material that was dropped on the plots was removed after each grazing. In the second treatment, the plots were clipped at each sampling date with a rotary mower with the blade set at 2.5 cm above ground level. All clipped forage was removed from the plots. In the control plot, there was no grazing or mowing during the growing season except for quadrates clipped to estimate production.

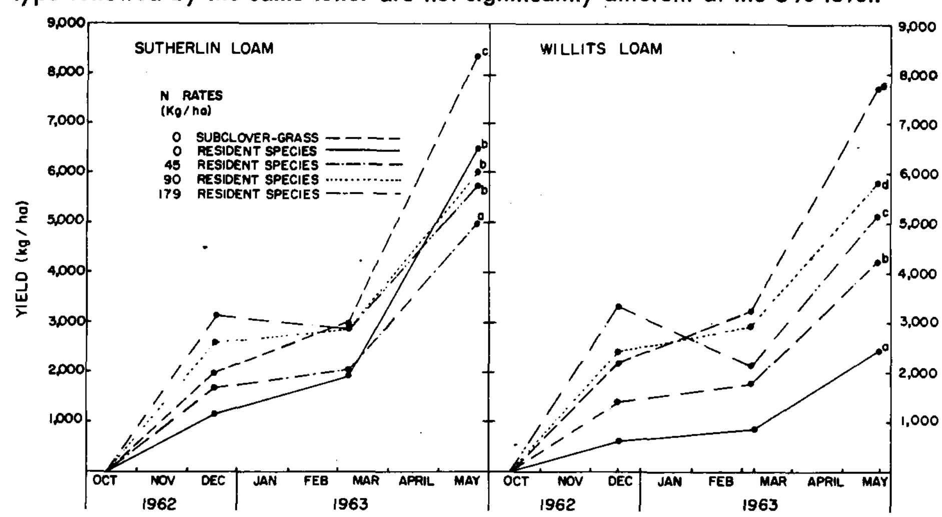
The eight fertility treatments were as follows: (1) Check; (2) Subclover seeded in October 1960 (which resulted in a good stand of subclover mixed with grasses during the three years of the study); (3), (4) and (5), 45, 90 and 179 kg N/ha respectively, applied in October 1960 and again in October 1962; (6), (7) and (8), 45, 90 and 179 kg N/ha respectively, each applied in October 1961. The size of individual subplots was 3.05 × 6.10 m.

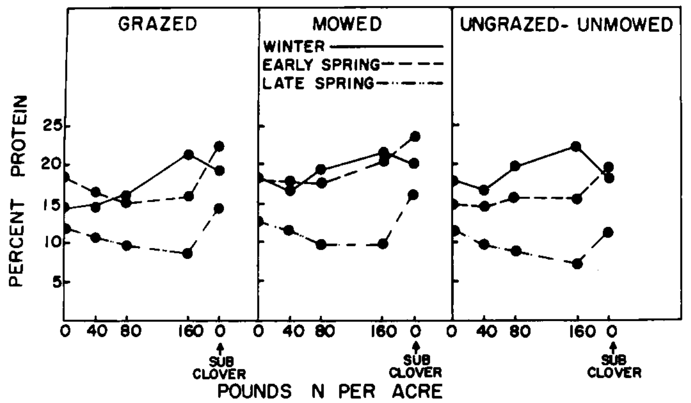
Plots were sampled in 1961 on February 20, April 3 and May 25; in 1962 on March 12, April 10, May 11, and Decem-

Graph 1. Forage production by subclover-grass and N-fertilized resident grasslands on Sutherlin loam (1961–62 growing season). Cumulative yield values followed by the same letter are not significantly different at the 5% level.

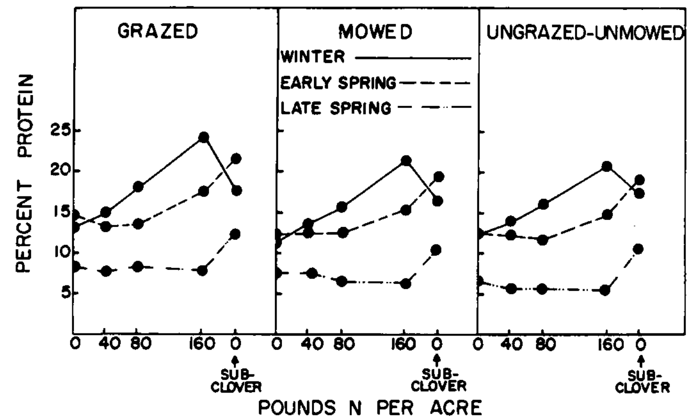


Graph 2. Forage production by subclover-grass and N-fertilized annual type grasslands on grazed plots (1962–63 growing season). Cumulative yield values within a soil type followed by the same letter are not significantly different at the 5% level.





Graph 3. Percentage of protein in forage from grazed, mowed, and ungrazed-unmowed plots on a Willits loam at different seasons of the year, as affected by increasing rates of N or seeding of subterranean clover. L.S.D. (.05) = 1.4% protein.



Graph 4. Percentage of protein in forages from grazed, mowed, and ungrazed-unmowed plots on a Sutherlin loam at different seasons of the year, as affected by increasing rates of N or seeding of subterranean clover. L.S.D. (0.5) = 2.4% protein.

ber 16; and in 1963 on March 7 and May 24.

Yields were estimated by clipping three quadrates (each 30.48 cm square) from each subplot at the dates specified above. The quadrates were clipped as close to the ground as possible (about 1 cm). The same quadrate was not clipped twice in one growing season. Thus, the forage clipped from the ungrazed-unmowed plots at any given date represented cumulative growth to that date of clipping. Cumulative yields from the grazed and mowed treatments were obtained by adding the increments of dry matter production during the three periods of growth.

Forage production

During the winter months of 1960–61 (the first year after subclover was seeded) subclover plots on the Sutherlin and Willits loam soil sites yielded no more than did the zero N plots, on each of the three management treatments. However, clippings taken April 3 and May 25, 1961 indicated that forage production from the clover plots was about equal to production from plots fertilized with 45 kg N/ha.

The response pattern to increasing rates of N is shown in graph 1. The cumulative production from the ungrazed-unmowed plots was greater than from grazed or mowed plots for the total season. There was a response to N fertilization on the ungrazed-unmowed plots at the spring sampling dates, but no N response was observed in the spring where plots were grazed or mowed earlier in the season.

The first rains of the 1961–62 season on the Sutherlin loam soil site that were sufficient to germinate the annual forage (see table) came in late November 1961 at a time when cool temperatures prevented rapid growth. There was ample moisture for plant growth through March 1962, but in April and May there was a moisture deficiency.

The clippings taken in March 1962 were the first of the season and represented winter growth (graph 1). On the Sutherlin loam soil, grazed treatment production increased with increasing rates of N; and the yields from the subclover treatments were slightly more than where 45 kg N/ha had been applied in October 1961. In the second growth period which ended in April, grazed plots seeded to subclover had the highest yields; those fertilized with 179 kg N/ha in October 1961 were next. This is indicated by the slopes of the lines representing the respective treatments in graph 1. After the April 1962 sampling, the weather was dry and the production was low; therefore, there were no significant differences among the treatments at the May sampling date.

Total cumulative production for the season increased with each increment of N applied. The forage produced on the subclover plots was 360 kg less but not significantly different from that produced on the 90 kg N/ha plots. The residual effect of N applied in October 1960 (not reported) was not significantly different in the 1961–62 season.

Pattern

The pattern of forage production through the growing season was quite different on the ungrazed-unmowed plots compared with the grazed or mowed plots. During the spring season forage production was higher on the ungrazed-unmowed plots and response to N fertilization was greater. Thus the increase in total cumulative production for the season due to application of N was much greater than where plots were mowed or grazed. The quantity of forage from plots with subclover was equivalent to that from plots receiving 45 kg N/ha. The residual effect of N was not significant.

On the Willits soil during the 1961–62 season, the pattern of response on the grazed plots was similar to that on the Sutherlin soil (graph 1), except that at the April sampling date, subclover treatment yielded an amount of forage about equivalent to the 90 kg N/ha treatment. During the extremely dry April, subclover plots were grazed heavily by the sheep. The sheep preferred the subclover plots at this time. With heavy grazing plus dry weather the subclover plots made poor recovery during April 1962, compared with Hardinggrass without subclover. There were significant amounts of lupine in the check plots where subclover was not planted and which did not receive N. Lupine made its most rapid growth late in the spring. The application of N or establishment of subclover reduced the contribution which lupine made to forage production.

Response

On the ungrazed-unmowed treatment on the Willits soil, yields from the March sampling of the zero N level were equal to those from the zero N level on the grazed treatment. Otherwise, the response to N throughout the season was similar to that reported for the Sutherlin soil in graph 1. Production from subclover plots was equivalent to the 45 kg N/ha treatment.

First rains initiating plant growth of the 1962–63 season came before mid-October 1962, and there was ample moisture for plant growth through May 1963. Forage production from the grazed treatments of the Sutherlin and Willits soils are shown in graph 2. Production during the fall is represented by samples clipped in December. On both soils, yields increased with increasing rates of N applied, and the subclover plots produced yields equivalent to slightly more than the yield from the 45 kg N/ha treatment applied in October 1962. The abundance of native clovers on the Sutherlin soil probably accounts for the relatively high yield on the check plot.

Samples

Samples taken in March 1963 represent growth which took place during the cool, wet winter period. Production from all treatments was quite low. Subclover plots yielded most, while the 179 kg N/ha treatments actually had less forage on them in March, before grazing, than was present in December, after grazing. It was apparent that a considerable amount of lush forage on the high N treatment rotted during the wet, cool period.

At the May 1963 sampling date there was a difference in the response pattern on the two soils. On the Sutherlin soil, production was less where application of N had been made the preceding fall than where no N had been applied. The suppression of native clovers by the increased growth of the grasses early in the season probably explains the relatively low production on the N plots during the spring period. The N applied in the fall was taken up by the grasses and removed by grazing in the two previous sampling periods. Production from the subclover treatment was higher than from any other treatment. In contrast, there were very few native legumes on the Willits soil in the spring of 1963, and production increased with increasing rates of N. Subclover plots had the highest spring yield.

Total cumulative production on Sutherlin soil during the 1962–63 season was highest (8,380 kg/ha) from the subclover plots, and second highest (6,500 kg/ha) from the resident species plots which received no N fertilizer—a reflection of the spring yields. On the Willits soil, highest cumulative production (7,710 kg/ha) also was on the subclover plots; however, a response to N was reflected in the total yield of grass plots. There was no significant residual effect on 1962–63 yields from N applied in October 1961 (data not reported).

The data for ungrazed-unmowed plots in the 1962–63 season are not given because they bear approximately the same relationship to grazed plots as in the 1961–62 season (graph 1).

Protein levels

Protein levels in the forage from the Sutherlin loam site are given in graph 3. The levels generally increased with increasing rates of N during the winter period. The level of protein in the forage from subterranean clover plots was greater than from plots where 80 lbs N had been applied, but less than where 160 lbs N had been added.

The levels of protein remained high in the spring, but the response to fertilization was somewhat different than in the winter period. On the grazed plots the application of N actually decreased the level of protein, as compared with the unfertilized plots, and the subterranean clover plots had the highest level of protein of any treatment. On the mowed and ungrazed-unmowed treatments, N had little effect upon the protein level except where 160 lbs per acre were applied to the mowed plots. But in each instance the subterranean clover plots had the highest level of protein.

Last sampling

At the last sampling date, when plants were approaching maturity, the effect of N on each of the management treatments was somewhat similar. Application of N decreased the level of protein, and the subterranean clover plots had the highest level. Forage from the ungrazed-unmowed plots was consistently lower in N than forage from the other management treatments. This was true for all levels of N and the subterranean clover treatment.

On the Willits soil the response to N fertilization at the first sampling date in late winter or early spring was consistent for all management treatments (graph 4). Each increment of N increased the level of protein in the forage; and forage from the subterranean clover plots was somewhat lower in protein than that from plots where the highest rate of N had been applied. As the season advanced the effect of the lower rates of N on protein level of the plants became insignificant while the level in the subterranean clover plots was relatively high. At the final sampling date there was no effect from N even at the highest rate and subterranean clover forage had the highest level of protein. Where N had been applied, the ungrazed-unmowed plots were lower in protein than the other management plots. Forage from mowed plots had less protein than forage from grazed plots.

Conclusions

Results of this study indicate an advantage for subclover-grass pastures compared with nitrogen fertilization of California annual grassland, in areas where the subclover can be established. Forage production and uptake of N was much more uniform throughout the growing season from subclover than from N fertilization. It appeared that where commercial N was applied, N was taken up rapidly, giving increased production and high protein levels within the plant early in the season; when this was removed by grazing or mowing, little N remained for future growth. The suppressive effect of the early rapid grass growth on legume populations remained through the season, resulting in low forage production, and low-quality livestock feed in late spring, on plots where N had been applied.

Leaving forage

If the forage was left unclipped or ungrazed, a large increase in production was realized from N fertilization during the spring as well as the winter. However, this large volume of feed was low in quality because legumes were practically eliminated and the percentage of protein in the grasses themselves was often reduced by N fertilization.

Since there was no residual effect from N applications, they must be repeated each year. In contrast, once subclover is established, a good stand can be maintained for many years by proper grazing and maintenance applications of P and S. Adequate levels of P and S must also be supplied to obtain best results from N fertilization.

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