Journal of

American Society of Range Management

The American Society of Range Management was founded in 1948 and incorporated in 1949 under the laws of the State of Wyoming. Among the Society's purposes are to seek a comprehensive understanding of range ecosystems and of the management and use of range resources; to assist all who work with rangeland to keep abreast of new findings; to improve the effectiveness of range management in obtaining from range ecosystems the products and values necessary for man's welfare; and to create a public appreciation of the social and economic benefits to be derived from range resources. Membership in the Society is open to anyone engaged in or interested in any aspect of the study, management, or use of range ecosystems.

JOURNAL OF RANGE MANAGEMENT

The *Journal of Range Management* is published bimonthly by the American Society of Range Management. It serves its readers as a forum for the presentation and discussion of ideas and facts related to the study, management, and use of range ecosystem resources. Accordingly, all material published herein is signed and reflects the individual views of the authors and not an official point of view adopted by ASRM.

Subscriptions. The subscription price for members of the Society is included in the annual membership dues. For all others the subscription price is $15.00 per year to all countries. Subscriptions are available only on a calendar year basis. Subscribers outside the United States should remit payment in US dollars by International Money Order or by draft on a New York bank.

Address Changes. Notice of change of address should be received by the Managing Editor no later than the first day of the month of issue. Provide both old and new addresses. Copies lost due to change of address cannot be replaced unless adequate notice has been given. To assure forwarding, provide your local postmaster a *Change of Address Order* (POD Form 3575) indicating thereon to guarantee forwarding postage for second-class matter.

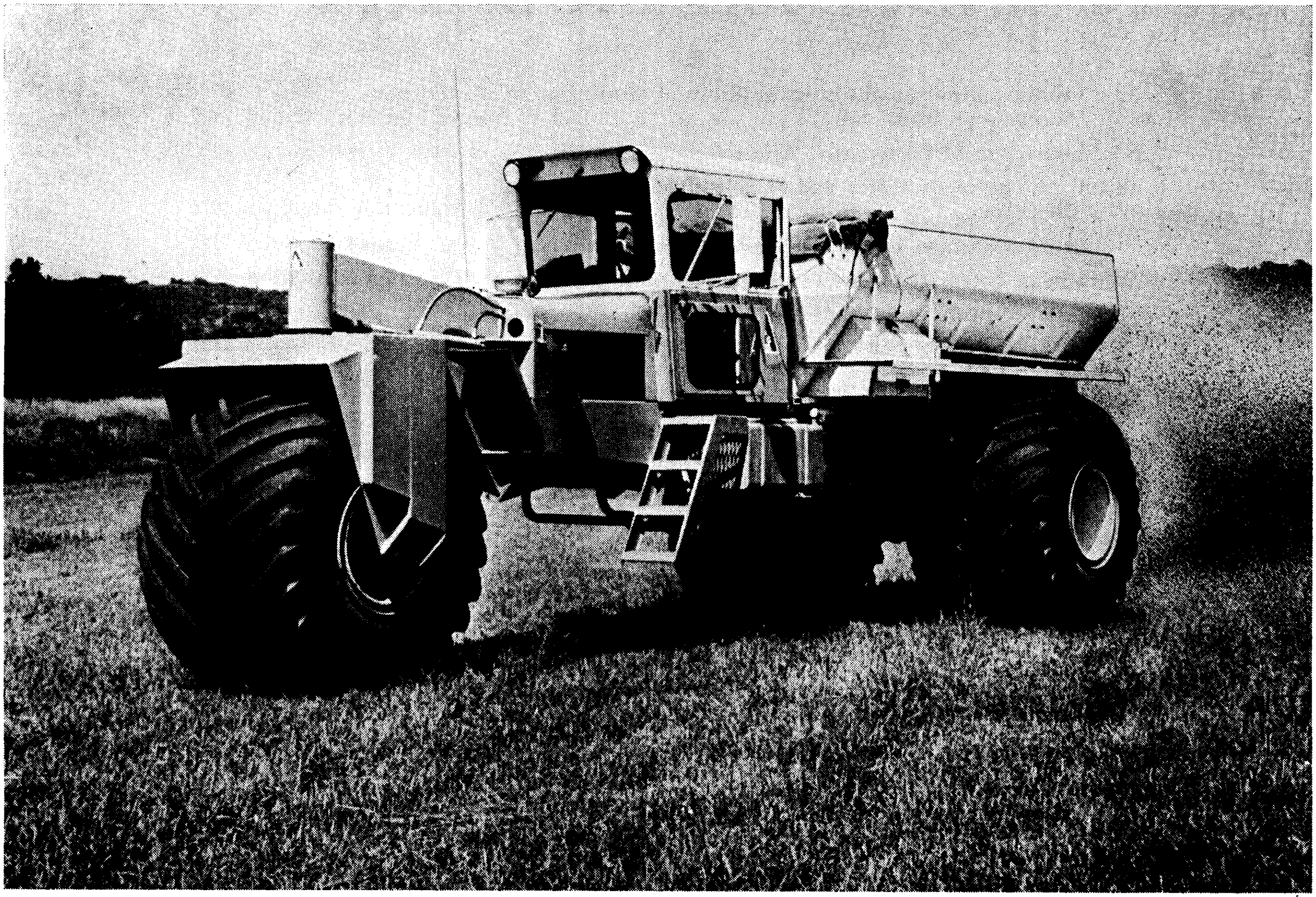
Business Correspondence. Concerning advertising, subscriptions, back issues, single copy prices, and related matters, address correspondence to Managing Editor, 2120 South Birch Street, Denver, Colorado 80222.

Editorial Correspondence. Concerning manuscripts and other editorial matters, address correspondence to Editor, 624 South Shields Street, Fort Collins, Colorado 80521. "Instructions for Authors" appears in the March issue of the Journal each year. Copies are available from the Editor.

Reprints. Individual reprints of articles appearing in the Journal are obtainable only from authors or their institutions. Authors may order reprints in lots of 100 or more through the Managing Editor.

Second-class postage paid at Denver, Colorado, and at additional mailing offices.

Printed in the USA by Allen Press, Inc., 1041 New Hampshire Street, Lawrence, Kansas 66044.



Journal of RANGE MANAGEMENT *Volume 23 Number 5 September, 1970*

RE = Con Resumen en Español por Donald L. Huss y E. Hernandez, Dep. de Zootecnia, ITESM, Monterrey, N.L., Mexico.

Cover Photo—Lana Vetch, Used to Control Medusahead, is Relished by Cattle.

See Article by Robert S. Mac Lauchlan, Harold W. Miller, and Oswald K. Hoglund, page 351.

An Economic Analysis of Optimum Rates of Grazing in the California Annual-type Grassland[1]

JACK F. HOOPER AND H. F. HEADY

Vice President, Armendaris Land Development Corporation, Kansas City, Missouri;[2] and Professor, School of Forestry and Conservation, University of California, Berkeley.

Highlight

In the early days of the west, marketing practices, low costs associated with grazing and lack of knowledge about range management led to heavy and sometimes destructive utilization of range vegetation. As the field of range science developed, control of grazing to achieve "moderate" utilization became an important management tool. However, too little attention has been given to the economics of "moderate use" recommendations. This study indicates the optimum rate of utilization on a Sutherlin soil in the annual-type grassland of California leaves approximately 500 lb./acre of plant residue. Examination of opportunity costs indicates the economic loss from heavy grazing is several times that of light use. Thus, range managers who recommend "moderate" or even "light" grazing are in effect advocating a small loss (opportunity cost of light grazing) as insurance against a larger loss (opportunity cost of heavy grazing).

When hides were a principal range livestock product and cattle sold by the head, operators owned large numbers of animals and believed that heavy utilization of natural grasslands was economically expedient. Later, when meat production was important, but livestock were still sold primarily by the head, heavy grazing continued. The price per head was virtually independent of the animal's physical condition. Still later, when an animal's condition affected price, the practice of "first come first served" on public domain lands resulted in heavy use. Low costs associated with range use also dictated that grazing be heavy (Hooper, 1967).

Beginning about the turn of the century, both fixed and variable costs associated with grazing of range lands began to increase, raising the marginal costs of grazing. Thus, a more moderate degree of utilization was required to obtain an operation where marginal revenue equaled marginal cost (Hooper, 1967). Also, as lands came under private ownership, or government trusteeship, management for sustained grazing was associated with moderate use.

Under the technological and economic conditions prior to World War II, control of stocking rates, utilization, and distribution were the most expedient methods of grassland management. Today, fencing on extensive range land, seeding with introduced species, fertilization, brush control, and other practices neither technically nor economically possible even thirty years ago are feasible. Applications of these practices have tended to de-emphasize the importance of livestock control as a grassland management tool. However, management of stocking rate and rate of herbage utilization still have an important place in range ecology and in economics. That place is likely to become more important because prices and property taxes are forcing livestock operators to seek methods of spreading fixed costs; one of these methods is increased stocking rates. This study was designed to ascertain the economic impact of leaving various amounts of herbage residue (mulch) on subsequent herbage production in the California annual-type grassland.

Variables Affecting Herbage Production

In an economic analysis the technical relations between inputs and outputs (the production function) must be known or estimated before prices can be applied to determine optimum levels of inputs and outputs for profit maximization. Thus, the variables affecting herbage production in this study are identified as follows:

Soils, being the reservoir of nutrients and water, are an important variable in determining forage production. Therefore, separate functions must be derived for different soils or groups of soils. Data analyzed here come from one soil (Sutherlin gravelly clay loam) in one location on the Hopland Field Station in California. The site had less than 5% slope and little erosion hazard.

Weather, especially rainfall, is an important determinant of forage production. In the California annual-type grassland, total rainfall and especially timing of the rain seem to be more important in determining total production, than other climatic factors. Rains occurring in March, April, and May, when temperatures are ideal, influence production more than comparable amounts at other seasons. Consequently forage production functions are expected to differ year by year and they certainly vary season by season.

Natural mulch is one of the most important determinants of forage production in the California annual-type grassland. Even in the absence of grazing, removal of all mulch by clipping before the first rain in the fall: (1) reduced the proportion of desirable forage species in the stand, (2) lowered forage quality, and (3) reduced subsequent forage production as compared to

[1] Received September 15, 1969; accepted for publication February 19, 1970.

[2] Also, Professor Resource Economics and Ecology, Utah State University, Logan.

areas where mulch had not been removed (Heady, 1956, 1965).

The grazing animal exhibits preferences for certain forage species (Heady and Torell, 1959; Van Dyne and Heady, 1965). These "preferred species" tend to be grazed more heavily than less desirable species and may tend to decrease in the annual grassland community. Among the preferred species are the perennial grasses such as *Stipa pulchra*, and annual grasses such as *Avena barbata*, *Bromus mollis*, and *Bromus rigidus*. Under heavy grazing, these tend to be replaced by annual grasses of lower stature such as *Aira caryophyllea* and *Festuca dertonensis*. If extra heavy use and trampling occur, annual forbs such as *Baeria chrysostoma* dominate. Thus, herbage production is lowered and species composition changed as a result of selective grazing and intensity of grazing. Heavy grazing also reduces to low quantities the amount of mulch which remains on the ground at the time of fall seed germination.

As vegetational responses to heavy grazing (changes in species composition, production, and forage quality) could be simulated with a single manipulation of mulch before the first fall rain, mulch or plant residue may be the most important controllable grazing factor in the California annual type (Heady, 1956). Being annual, the vegetation is more responsive to conditions of germination and establishment in the fall than to food accumulations in the spring and early summer.

Several investigators, recognizing the importance of mulch in the California annual type, have made the recommendation that under correct utilization two inches of stubble should be on the ground when new growth starts in the fall (Bently and Talbot, 1951; Hormay and Fawsett, 1942; Hormay, 1960). Heady (1956) in discussing the importance of mulch did not make a recommendation, but estimated the relation between forage production and mulch in lbs./acre to be $Y = 1214 + 0.354X$ where Y = forage production in the spring and X = forage residue or mulch left the preceding fall. However, nowhere in the literature are there ecological and economic evaluations of mulch amounts which could suggest optimum rates of utilization.

Table 1. Average forage production (lb./acre) in relation to mulch 1956 through 1960.

	Pounds of mulch per acre					
Years	0	500	1000	1500	2000	2500
1955–56	794	2012	2118	1724	1966	1974
1956–57	1800	2477	1947	2840	2777	2534
1957–58	576	3498	3361	3344	3682	3571
1958–59	411	2092	2117	2046	2353	2063
1959–60	897	1808	1955	1834	1907	1873
Average	895	2377	2300	2358	2543	2403

Estimating the Herbage Production Function

The fact that the results of grazing could be duplicated so strikingly through mulch removal provided a vehicle for assessing the relationship between utilization and production; for estimating a herbage production function as influenced by grazing. Herbage could be clipped and weights taken of both "forage" and mulch. For this study production data were obtained from a clipping study which was conducted at the University of California, Hopland Field Station in the years 1955 through 1960. Six mulch quantities in a Latin square design (plots 10 × 10 ft) on Sutherlin soil were obtained in September and measured for herbage production the following May. The treatments were: (1) all mulch removed; (2) 500 lb./acre of mulch returned; and (3) 1000 lb. returned; (4) 1500 lb. returned; (5) 2000 lb. returned; and (6) 2500 lb. returned. Production is on a basis of oven-dry weights from square foot plots.

Advantages and disadvantages of using clipping studies to simulate grazing have been reviewed by Culley, Campbell, and Canfield (1933). They concluded that when the amount and kind of forage removed are the same, grazing is probably more harmful than clipping. Heady (1961) concluded that continuous clipping may be more harmful because an individual plant is not necessarily grazed continuously even though the pasture may be. In the California annual-type grassland, where amount of mulch at the time of germination plays such a dominant role, it is assumed for this study that differences attributable to grazing or clipping are of little consequence.

An attempt was made to fit the clipping data to a statistical production function as suggested by Heady and Dillon (1961). Except for the zero mulch treatment, all others gave approximately the same herbage yield (Table 1). As many biological functions exhibit curvilinear relationships the results were unexpected. Since there were no observations between zero and 500 lbs., one cannot be positive where the breaking point occurs. Apparently, however, the breaking point (and the curvilinear portion of the relation if it exists) is in the neighborhood of 500 lb. of mulch per acre.

Of interest but not to be explored in this paper, is that even 2500 lb./acre of mulch did not depress herbage production. The curve of herbage production has a broad-flat surface.

Pricing Herbage

To make an economic analysis, the relationship between the value of herbage and the value of mulch must be established. There are at least three methods for pricing herbage: (1) rental value; (2) hay equivalent; and (3) cost of owning land. Based on rentals at $3.00 to $6.00/AUM (AUM = 1000 lbs. of usable forage), herbage is valued at from $0.003/lb. ($3.00 ÷ 1000 lb.) to $0.006 ($6.000 ÷ 1000 lb.). Based on unharvested "wild" hay values of from $10.00 to $30.00/ton, herbage would be valued at from $0.005/lb. ($10.00 ÷ 2000 lb.) to $0.015 ($30.00 ÷ 2000 lb.). With land selling at prices in excess of $1000/AUY (AUY = 12,000 lbs of usable forage) the price of herbage would be about $0.005 (interest on investment @ 6% = $60/AUY = $0.005/lb.). Thus, herbage values range from $0.003 to $0.015/lb. These are reasonably realistic assumptions which bracket actual prices over much of the range country. In analyzing an actual ranch situation, local circumstances would determine the appropriate price of herbage. In this study $0.005 ($5.00/AUM or $10/ton hay) is used as a representative figure.

Pricing Mulch

Attaching a value to mulch is a more difficult matter than pricing herbage. One way to view mulch is that it is simply herbage which could have been used, but wasn't. In this case, mulch would have the same price as herbage.

Although the argument is not resolved, there is considerable evidence to indicate that the best system of grazing in the California annual-type grassland is a yearlong continuous grazing system (Heady, 1961). Under this system, species, plants, and plant parts (such as seeds and leaves) are grazed selectively and the preferences change through the season (Heady and Torell, 1959; Van Dyne and Heady, 1965). By the end of the grazing season (near the time of the first rain), the most desirable species, plants and plant parts have been utilized leaving the least desirable species, plants and plant parts as residue or mulch. Protein content of clipped herbage samples indicates the quality in September is about ⅔ that in June. Chemical analyses of dietary samples collected with esophageal fistulated cattle and sheep also indicated quality decreased by ⅓ from June to September (Van Dyne and Heady, 1965A). Several studies (Hart, Guilbert, and Goss, 1932; Gordon and Sampson, 1939; Van Dyne and Heady, 1965A) indicate protein levels in the period July–October to be less than 5% of the herbage weight, while for late winter to early summer the protein content averages above 10%. Other measures likewise suggest lower quality in the July–October herbage residue than in the forage during November–June. Based on these data, herbage residue would have to be priced at the average yearlong value of herbage ($0.005 at $5.00/AUM or $10/ton) to one half the herbage value ($0.0025).

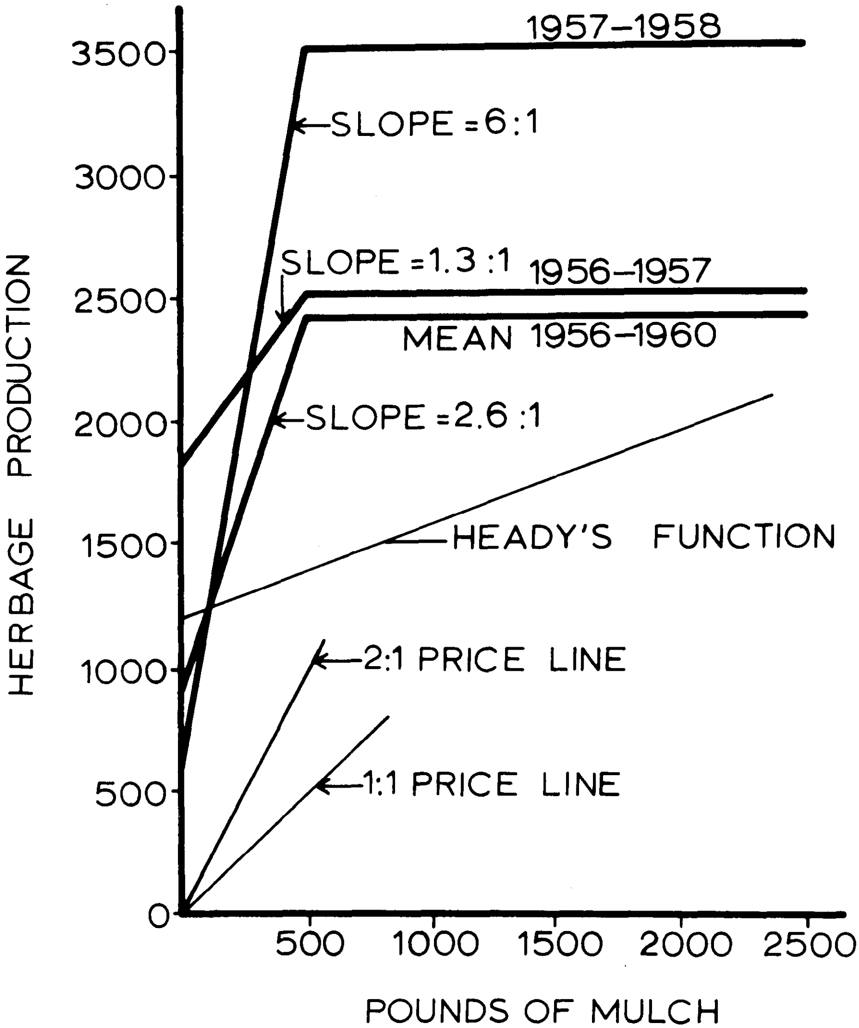


Fig. 1. Relationships of herbage production (lb./acre) in the spring to mulch the previous fall on Sutherlin Soil, Hopland Field Station, California.

Perhaps more important for purposes of economic analysis than deriving absolute prices for herbage and mulch is to establish ratios of prices. From the above analyses, the ratio of prices of herbage to mulch would appear to fall between 1 to 1 and 2 to 1.

One additional factor which must be included in fixing the price of mulch is its role in preventing erosion. In the mulch treatments mentioned above, no erosion occurred on any of the plots that had mulch. The bare plots showed erosion in early fall during the first rain, especially if that rain was intense. Within 3 or 4 weeks after the soil was wet, the new plants had grown enough to protect the soil and no further evidence of erosion was noted (Heady, 1956). Observation indicates erosion will occur with amounts of mulch near zero on Sutherlin soil. Perhaps, at amounts less than 200 lb./acre the role of herbage residue in preventing and reducing erosion may cause mulch value to be raised considerably. How high its price might rise in relation to herbage is pure conjecture at this point, as it is difficult to put a price on "prevention of erosion." Because erosion was not a serious factor on the Sutherlin soil, allowance for the value of mulch for erosion control was not considered.

The Optimum Rate

The data (Table 1) indicate that leaving more than 500 lb./acre of mulch would not pay. Although there are no data available for the range 0–500, the optimum amount of mulch to be left (the breaking point of the curves in Fig. 1) is probably less than 500 lbs on this Sutherlin soil.

If one assumes a breaking point of 500 lb., the sloping segment rises at a ratio of 2.6:1 for the average of the 5 years (Fig. 1), that is, 500 lb./acre of mulch returns about 1300 lb. of herbage. The most shallow slope, 1.3:1, was for 1956–57, and the steepest, 6:1, during these 5 years was in 1957–58. A price line indicative of a price ratio of 1:1 (45 degrees) between herbage and mulch would be tangent to any one of the curves in Figure 1 at the point of discontinuity (500 lb. of mulch). The point of tangency of the price line and the production response curve is the optimum amount of mulch to leave (Heady and Dillon, 1961). For the optimum to shift to zero mulch in a 1957–58 type relation, the price ratio of herbage to mulch would have to be 6:1. For a 1956–57 type year, if the price of herbage were 1.3 times that of mulch, the point of tangency and the optimum would be shifted to zero amount of mulch. For the average of the five years, the price ratio would have to be 2.6:1 in favor of herbage over mulch to justify complete utilization. Put another way, so long as herbage prices are not more than 2.6 times that of mulch, the last 500 lb. of mulch is worth more as a resource than as a product.

The shift to zero mulch (or complete utilization) might occur in a poor herbage year such as 1956–57, when the spread between the treatments is small. And then the shift to zero mulch would occur only if for some reason herbage can be valued at a price greater than 1.3 times the price of mulch. However, since the point of discontinuity probably occurs at a value less than 500 lb. of mulch, the price ratio may still be slightly greater than 1.3 to 1.

In the case of Heady's function $Y = 1214 + 0.354X$, with herbage valued at the same price as mulch (price ratio 1 to 1), or higher, the optimum degree of utilization is that which removes all mulch. Since, on a purely chemical basis, plant residue would never be valued higher than forage, one would conclude that all herbage and plant residue should be removed every year.

Heady's function was for only two years and did not include mulch treatments in the sensitive range between 0 and 1000 lb./acre. Even if these data are representative, one can still argue that some amount of mulch, say 200 pounds, is needed for erosion control. The susceptibility to erosion of different soils and its effect on future production, the value of down stream developments, and potential damage by siltation, would all be factors to be considered. Because these factors vary by soil and by geographic location, the value of mulch in erosion control will vary, the price line will vary, and the optimum amount will also vary.

Opportunity Cost of Light or Heavy Grazing

The optimum rate of grazing (utilization) on Sutherlin soil is that which leaves approximately 500 lb. of plant residue. What are the consequences of grazing at other than the optimum rate? The consequences can be evaluated in terms of opportunity costs which are the profits of one decision foregone by making a different decision (Heady, 1957). For light grazing it is the profits foregone by not using all the forage.

The 2-inch stubble height recommendation mentioned earlier was based on conditions in Madera County in the foothills of the Sierra Nevada Mountains. This recommendation, however, has become a rule of thumb for other parts of the state. It is therefore, of interest to see the effect of the application of this rule to the Sutherlin soil on which the previously described mulch experiments were conducted. A clipping study was conducted during the years 1957–58 and 1958–59. Treatment I was clipped at a stubble height of 1¼ inches while Treatment II was clipped at 2½ inches. All clipped herbage was removed so that only stubble remained. This stubble was then clipped to ground level, removed and weighed. The results indicate that under 1957–58 conditions a 2-inch stubble height corresponded to 1300 lb./acre of mulch. Under 1958–59 conditions, a 2-inch stubble height amounted to 1100 lb. of mulch.

If the optimum amount of plant residue to be left were 500 lb. and by the 2-inch rule approximately 1000 lb. were left, this would amount (with residue priced at \$0.0025/lb. or one-half the herbage value) to \$1.25/acre in foregone profits (500 lb. at \$0.0025). The opportunity cost would be \$2.50/acre if residue were priced at \$0.005, and \$3.75/acre if priced at \$0.0075. On 1000 acres, this is \$1250, \$2500, or \$3750.00. From the above, it is evident that the opportunity cost of light grazing becomes more important on ranches where herbage assumes a high value due to high land prices.

The opportunity cost of heavy grazing is expressed in terms of the lost forage the next year. In a

1956–57-type year, taking the last 500 lb. of mulch gives a return of 1800 lb. the next year (Fig. 1) and leaving the last 500 lb. as mulch gives a return of 2500 lb. the next year. The difference is 700 next year minus 500 harvested this year which equals a net loss of 200 lb. of herbage. Disregarding a discount rate, this is equal to a loss of $1.00/acre (200 lb. at $.005). At a price of $0.0075, the loss is $1.50. In a 1957–58-type year, the difference is 3500 – 600 = 2900 – 500 for a net loss of 2400 lb./acre, which is valued at $12.00/acre (2400 at $.005) or $18.00/acre (2400 at $.0075). For the five year average values, the opportunity costs of leaving no mulch are $5.00/acre and $7.50/acre at the two prices in comparison with leaving 500 lb./acre.

Conclusions

The optimum rate of grazing (utilization) on Sutherlin soil at the Hopland Field Station appears to be that which leaves approximately 500 lb. of herbage residue (mulch) at the time of the first rains in the fall.

Although the economic principle of spreading fixed costs is of importance in California grassland management, spreading of fixed costs and heavy utilization should not be confused. Spreading the fixed costs of investments and taxes by grazing to a point where the mulch is completely removed does not seem economically expedient on Sutherlin soils. The economic effect of complete herbage removal (overgrazing) appears to cost $5 to $7/acre in foregone returns while the cost of light grazing is $2.50 to $3.75. That is, the opportunity cost involved in heavy grazing (removing 500 lb. too much mulch) is several times greater than the opportunity cost of light grazing (adhering to the widely accepted 2-inch or 1000 lb. of mulch rule). One wants to graze at the correct (optimum) rate for maximum economic returns. However, if he makes a mistake, he wants to make it grazing too lightly. Adhering to the 2-inch rule is the lesser of two evils and may be rationalized as insurance against a larger economic loss.

It is dangerous to export these conclusions to other soils and other geographic areas within the California annual-type grassland. They should not be applied directly to perennial grasslands. These findings are an indication that definitive work needs to be done in several areas, each including a wide range of mulch treatments. The procedure potentially can place range forage utilization on sound economic as well as ecological grounds.

Literature Cited

Bentley, J. R., and M. W. Talbot. 1951. Efficient use of annual plants on cattle ranges in California foothills. U.S. Dep. Agr., Circ. No. 870.

Culley, M. J., R. S. Campbell, and R. H. Canfield. 1933. Values and limitations of clipped quadrats. Ecology 14:35–39.

Gordon, A., and A. W. Sampson. 1939. Composition of common California foothill plants as a factor in range management. Cal. Agr. Exp. Sta. Bull. 627.

Hart, G. H., H. R. Guilbert, and H. Goss. 1932. Seasonal changes in the chemical composition of range forage and their relation to nutrition of animals. Cal. Agr. Exp. Sta. Bull. 543.

Heady, E. O. 1957. Economics of agricultural production and resource use. Prentice Hall, Inc. 850 p.

Heady, E. O., and J. L. Dillon. 1961. Agricultural production functions. Iowa State University Press, Ames, Iowa. 667 p.

Heady, H. F. 1956. Changes in a California annual plant community induced by manipulation of natural mulch. Ecology 37:798–812.

Heady, H. F. 1961. Continuous vs. specialized grazing systems—review and application to the California annual type. J. Range Manage. 14: 182–193.

Heady, H. F. 1965. The influence of mulch on herbage production in an annual grassland. Proc. 9th Intern. Grassland Congr. 391–394.

Heady, H. F., and D. T. Torell. 1959. Forage preference exhibited by sheep with esophageal fistulae. J. Range Manage. 12:28–34.

Hooper, Jack F. 1967. Potential for increase in grazing fees. J. Range Manage. 20:300–304.

Hormay, A. L., and A. Fawsett. 1942. Standards for judging the degree of forage utilization on California annual-type ranges. Calif. For. and Range Exp. Sta. Tech. Note-21.

Hormay, A. L. 1960. Moderate grazing pays on California annual-type ranges. U.S. Dep. Agr., Forest Serv. Leaflet No. 239.

Van Dyne, G. M., and H. F. Heady. 1965. Botanical composition of sheep and cattle diets on a mature annual range. Hilgardia 36:465–492.

Van Dyne, G. M., and H. F. Heady. 1965A. Dietary chemical composition of cattle and sheep grazing in common on a dry annual range. J. Range Manage. 18:78–85.

A Comparison of Factors that Affect Ranching Profits[1]

LORENZ F. BREDEMEIER

Range Conservationist, U.S. Department of Agriculture, Soil Conservation Service, Fort Worth, Texas.

Highlight

To evaluate the impact of income and expense factors for beef cow–calf operations, 39 factors were identified. Using these, eight were evaluated independently for impact. A $10.00 difference in net return per cow resulted from the following changes: 57.2 pounds selling weight per calf; 3.6 cents per pound of calf weight sold; 10.3 percent calf crop; $4.02 per ton for hay; 12.2 months of pasture versus hay with hay at $14.00 per ton or 4.1 months with hay at $18.00 per ton; .2 animal unit months per acre in stocking rate; $25.30 per acre grazing land value; and $9.04 tax per animal unit. The input required to produce these changes and others related thereto must be assessed for each individual case before making resource use decisions for increasing income.

Range conservation and profits for the rancher are compatable objectives. Among the more frequent ways suggested for ranchers to increase profits are: heavier weaning weights, higher percentage calf crop, shorter feeding and supplementing periods, more productive forage, better quality forage, and timely selling for highest price.

Many studies using budgets have been made to help find the most profitable combinations of resources and enterprises. Hottel and Arnold (1965) presented budgets for alternative conditions in Arkansas. Oliver and Kline (1965) developed budgets for optimum enterprise combinations for beef cow–calf farms in southwestern Virginia. Olson (1959) used linear programming to select the best combinations of enterprises in eastern Ohio.

There is a continuing need to find new ways for landowners and operators to use economic data for increasing profits in harmony with good range conservation management. An approach for evaluating the impact of economic factors on the profits of a cow–calf operation is presented. The objective is to evaluate the relative impact of several factors on profits.

Procedure

Thirty-nine factors that influence returns to labor and management of a beef cow–calf operation were identified (Table 1). Values for each ranged from low to high based on data from ranchers' experience, publications in literature cited, and knowledgeable judgment. This range was divided into five equal units, "low," "medium low," "medium," "medium high," and "high." Any value may represent a rancher's three to five year average.

Table 1 is arranged into eight groups as used to figure: (1) herd organization, (2) gross income, (3) livestock investment and interest, (4) miscellaneous livestock expense, (5) pasture charge, (6) hay cost, (7) protein supplement cost, and (8) shelter and building charge.

A herd organization model was developed for a 150-cow herd using the "medium" values in Table 1. Forage and feed needs were determined using an adaptation of the summary table (Rasmussen, 1958). The "medium" values of all factors were used to figure income and expense to the nearest dollar for a 150-cow herd (Table 2). The minus return to labor and management is disturbing, but it emphasizes realities. There are, however, plus values such as interest return to land and building investments, and land value appreciation. There may be other long term benefits as effect on water supply, value of land for recreation, and conservation of resources for future generations as pointed out by Ciriacy-Wantrup and Schultz (1957).

The minus return provokes speculation as to changes that could produce a profit. However, the focal point of this project is which factor has greatest influence on net returns. Eight factors were selected for this analysis. They are calf selling weights, calf selling price, percent calf crop, hay cost per ton, months grazing versus months haying, stocking rate (forage production), value of grazed land, and livestock property tax. All except livestock property tax are directly related to resource use. They are considered to have major influence on net income depending on the cost of achieving the changes. Net return was calculated at all five values with "medium" value used for all other factors. Thus the effect of the single factor on net return was projected.

Results

Net returns for a 150-cow herd from different calf sale weights and prices range from a minus $6,141 to a plus of $684 (Table 3). A plus return to labor and management resulted from 450 pound calves at 30 cents with all other income and expense factors at "medium" value. To determine the influence of a factor, differences in net income resulting from changes for a factor were determined using Table 3. Analysis of weight influence revealed that 25 pound changes in calf weight at 20 cents per pound resulted in $525 difference in net income. The difference averaged $656.50 at 25 cents and $787.50 at 30 cents. When the influence of price was considered, 2.5 cents per pound produced an average difference of $918.75 for 350 pound calves. It averaged $1,050 for 400 pound calves and $1,181.25 for 450

[1] Adapted from paper presented at the annual meeting of the American Society of Range Management held in Calgary, Alberta, Canada, February 11–13, 1969. Received April 5, 1969; accepted for publication December 8, 1969.

Table 1. Management factors that influence net income of beef cow–calf ranches and values for each.

	Factor	Unit	Value Low	Med-low	Medium	Med-high	High
1.	Cows	No.	50	100	150	200	250
2.	Cows/bull	No.	20	30	40	50	60
3.	Death loss—cows	%	1	1.5	2	2.5	3
4.	Replacement ratio	%	5	10	15	20	25
5.	Calf crop	%	75	80	85	90	95
6.	Sell weight cull cows	lb	800	900	1000	1100	1200
7.	Sell weight cull bulls	lb	1100	1200	1300	1400	1500
8.	Sell weight calves	lb	350	375	400	425	450
9.	Sell price cows	¢	12	14	16	18	20
10.	Sell price bulls	¢	12	14	16	18	20
11.	Sell price calves	¢	20	22.5	25	27.5	30
12.	Investment/cow	$	150	175	200	225	250
13.	Investment/bull	$	300	400	500	600	700
14.	Investment/repl. heifer	$	100	125	150	175	200
15.	Investment/repl. calf	$	80	90	100	110	120
16.	Interest rate on investment	%	5	5.5	6	6.5	7
17.	Ins.—livestock/$100	¢	36	38	40	42	44
18.	Taxes/AU year	$	1	1.5	2	2.5	3
19.	Vet. & Med./AU year	$	1	1.5	2	2.5	3
20.	Salt & Min./AU year	$	.25	.50	.75	1.00	1.25
21.	Selling cost/head	$	.50	1.50	2.50	3.50	4.50
22.	Livestock Equipment Inv.	$	1000	1250	1500	1750	2000
23.	Amort. Equipment Cost	$	136	170	204	238	272
24.	Months pasture	No.	4	5	6	7	8
25.	Land value/acre	$	25	50	75	100	125
26.	Stocking rate	AUM/A	.5	.75	1.0	1.25	1.5
27.	Land tax/acre	$	.25	.50	.75	1.00	1.25
28.	Fence cost/acre	$	.15	.30	.45	.60	.75
29.	Water cost/acre	$	.05	.10	.15	.20	.25
30.	Months hay feeding	No.	4	5	6	7	8
31.	Hay Fed/AU day	lb	20	22.5	25	27.5	30
32.	Hay cost/ton	$	10	12	14	16	18
33.	Months protein fed	No.	2	3	4	5	6
34.	Protein fed/AU day	lb	.5	.75	1.00	1.25	1.5
35.	Protein price/ton	$	70	75	80	85	90
36.	Lvstk. building value	$	6000	8000	10000	12000	14000
37.	Amortized building cost	$	436	581	726	871	1016
38.	Building insurance/$100	¢	45	50	55	60	65
39.	Building maintenance @ 2%	$	120	160	200	240	280

pounds. This illustrates the interrelated effect of two variables.

The same kinds of calculations were made and tables developed for land values and stocking rates, percent calf crop and selling price, and for grazing versus haying and hay price. Net return and difference also were calculated for different personal property tax rates on livestock. This is a minor factor for influencing income as evidenced by the magnitude of change needed.

When the differences in net income were plotted the result was essentially a straight line for sale weight, sale price, cost of hay, percent calf crop, and land values. The month's grazing versus haying line was almost straight. It was governed by small differences in the monthly needs for animal unit months. Differences in net return due to changes in stocking rate produced a curved line. Differences were greater at lower stocking rates than at higher. This is because uniform stocking rate increment represents a higher percentage change at lower rates.

A common base is essential to compare the impact of different factors. Ten dollars per brood cow was chosen as a meaningful unit for comparison because this difference in income per brood cow in a herd seems significant. The differences resulting *if* the value of only one factor changed and all others remained at the "medium" value were used in calculating the comparison. The results are expressed as the amount of change in value of a factor needed to produce a $10 difference in net return per cow. They are 57.2 pounds selling weight per calf; 3.6 cents per pound calf weight sold; 10.3 percent calf crop; $4.02 per ton for hay; 12.2 months of pasture versus hay change with hay at $14.00 per ton, or 4.1 month's change with hay at $18.00 per ton; .2 AUM's per acre in stocking rate; $25.30 per acre grazing land value; and $9.04 tax per animal unit.

These figures will not be the same in all situations for the factors shown. The number of month's change necessary with hay at $14 and $18 per ton illustrates this.

Most ranchers in northern latitudes of the United States find that net returns are increased markedly by longer grazing seasons and shorter hay feeding periods. Results indicate that the basis for the

Table 2. Net return calculations for a beef cow–calf ranch with 150 cows.

Herd information		
Cows kept to calve	150	
Replacement heifers @ 15%	22.5	
Replacement calves @ 15%	22.5	
Bulls @ 1 to 40 cows	3.75	
Total calves @ 85%	127.5	
Less replacement heifer calves	22.5	
Income		
Calves for sale	105	
Beef for sale (No. calves × 400 lbs.)	42,000 lbs.	
Income from calves @ .25		$10,500
Cows for sale after 2% death loss	19.5	
Beef for sale (No. cows × 1000 lbs.)	19,500 lbs.	
Income from cows @ .16		$ 3,120
Bulls for sale ⅓ per year	1.25	
Beef for sale (No. bulls × 1300 lbs.)	1,625 lbs.	
Income from bulls @ .16		$ 260
Total income		$13,880
Expense		
Investment		
Cows. Average No. for year × $200	$27,800	
Bulls. Average No. for year × $500	1,875	
Replacement heifers. Avg. No. for year × $150	3,375	
Heifer calves. Avg. No. for year × $100	750	
Total investment	$33,800	
Interest on livestock investment @ 6%		$ 2,028
Miscellaneous livestock costs		
Ins. livestock investment × $ .40/100	$ 135	
Taxes. Avg. No. AU for year × $2	332	
Vet & medical. Avg. No. for year × $2	332	
Salt & mineral. Avg. No. for year × $ .75	124	
Selling cost. No. head sold × $2.50	314	
Bull replacement. No. × $500	625	
Equipment cost. Amort. from table	204	
Total miscellaneous livestock costs		$ 2,066
Grazing cost		
Land charge. AUM's needed × $4.50	$ 4,445	
Land tax. Acres needed × $ .75	741	
Fence cost amort. Acres needed × $. .45	445	
Water cost amort. Acres needed × $ .15	148	
Total grazing cost		$ 5,779
Hay cost .375T × 994.5 AUM × $14/T		$ 5,221
Protein supplement cost 4 months × 165.75 Avg. AU's × $1.20		$ 796
Building costs		
Building cost Amort. from table	$ 726	
Building Ins. value × $ .55/100	55	
Building maintenance from table	200	
Total building costs		$ 981
Total expense		$16,871
Net return		$–2,991

$4.50 used as a cost per animal unit month for grazing is relatively high when compared to the low cost of $14 per ton for hay fed at 25 pounds per animal unit day.

This illustrates how low cost hay or other winter feed can help enhance profits. Such low costs are essential for ranchers in regions with long winter feeding periods. When hay was figured at $12 per ton and grazing at $4.50 per animal unit month, net income to labor and management was not affected by changing length of grazing and feeding periods.

This held true under the conditions used in this analysis when cost per ton is 2⅔ times the cost of an animal unit month of grazing. If hay is charged to the livestock enterprise at more than 2.66 times the animal unit month of grazing, the net return to labor and management can be increased by lengthening the grazing season within climatic limitations.

Management changes such as calving dates can influence income as demonstrated by Mueller and Harris (1967). Such changes influence income as their effect is reflected in the values of factors. Proper grazing use as contrasted with overuse can increase weights, percent calf crop, and may reduce livestock investment costs based on Soil Conservation Service experience in working with ranchers. The costs involved in producing the changes in factor values was not included in this analysis. Such costs must be considered in the application of cost and return analysis to resource uses. Individual ranchers must use their values for all factors when applying this procedure to analyzing their problems.

This entire procedure for calculating cost and returns under alternatives of factors showing return to labor and management for beef cow–calf operations has been programmed on a Soil Conservation Service computer.

Adaptations can be made for rapid computation of a rancher's data to guide his resource use decisions.

Table 3. Net returns and differences (dollars) from different calf sale weights (pound) and selling prices (dollars) based on a 150-cow herd.

Selling price	Calf sale weights					Average dollars/ 25 lbs.
	350	375	400	425	450	
.20	–6141	–5616	–5091	–4566	–4041	525[a]
.225	–5222	–4631	–4041	–3450	–2860	590.5[a]
.25	–4304	–3647	–2991	–2335	–1679	656.5[a]
.275	–3385	–2663	–1941	–1219	– 497	722[a]
.30	–2466	–1679	– 891	– 104	+ 684	787.5[a]
Average dollars at .025 per pound	918.75[b]	984.25[b]	1050[b]	1115.5[b]	1181.25[b]	

[a] Difference in net income due to 25 pounds change in calf sale weight.
[b] Difference in net income due to 2.5¢ per pound change in calf sale price.

Literature Cited

Beaty, E. R., J. D. Powell, J. C. Fortson, and F. B. Saunders. 1963. Production aspects of a beef cow–calf operation on grass pastures. J. Range Manage. 16:250–253.

Ciriacy-Wantrup, S. V., and A. M. Schultz. 1957. Problems involving conservation in range economics research. J. Range Manage. 10:12–16.

Doane's Agriculture Report. 1968. Do you know what it costs to keep a cow? Sep. 8, pp. 20–25.

Gerlow, A. R., and J. R. Campbell. 1965. Enterprise costs and returns for beef cattle, Southern Louisiana rice area. La. Agr. Exp. Sta. DAE, Res. Rep. No. 337.

High, T. W., Jr., E. J. Chapman, B. L. Whittenberg, and J. W. High, Jr. 1965. Fescue pastures, under different management systems, and orchardgrass-clover for yearlong slaughter steer production. Tenn. Agr. Exp. Sta. Bul. 385.

Hottell, J. B., and A. F. Arnold. 1965. Crop pasture, timber and livestock enterprises for the Boston Mountain and Ozark Highland areas of Arkansas. Ark. Exp. Sta. Rpt. Series 135, pp. 13–66.

Kearl, W. A. 1961. Cattle ranching in the Northern Plains area of Wyoming. Wyo. Agr. Exp. Sta. Mimeo Cir. No. 155.

Launchbaugh, J. L. 1957. The effect of stocking rate on cattle gains and on native shortgrass vegetation in west-central Kansas. Ft. Hays Branch Kan. Agr. Exp. Sta. Bul. 394.

Leithead, H. L. 1960. Grass management pays big dividends. J. Range Manage. 13:206–210.

Mueller, R. G., and G. A. Harris. 1967. Economics of selected alternative calving dates. J. Range Manage. 20:67–69.

Oliver, J. D., and R. G. Kline. 1965. Optimum enterprise combinations for beef cow and calf farms in southwest Virginia. Vir. Agr. Exp. Sta. Tech. Bul. 180.

Olson, R. O. 1959. Some opportunities for improving farm income in southeastern Ohio. Ohio Agr. Exp. Sta. Res. Bul. 832.

Rasmussen, L. H. 1958. Balancing livestock numbers, feed and forage on ranching units. J. Range Manage. 11:194–197.

Rieck, R. E., G. C. Pulver, and W. Henquinet. 1966. Beef cow costs and returns in northern Wisconsin. Wis. Agr. Exp. Sta. Res. Rep. 22.

Wells, A. R., and S. A. Eugene. 1966. Costs and returns of beef cow herds. Minn. Uni. Farm Business Notes No. 489.

Western, C., and A. W. Epp. 1965. The Nebraska sandhills ranch business, 1965 summary. Nebr. Uni., Agr. Col. Agr. Econ. Dep. Memo.

Willhite, F. M., and A. R. Grable. 1966. Greater profit from livestock in the intermountain west with efficient ranch management. J. Range Manage. 19:112–118.

THESIS: UNIVERSITY OF WYOMING

Diet Preference and Utilization Patterns of Elk in the Northern Big Horn Mountains, Wyoming, by George E. Probasco. M.S. Range Management, 1968.

Data were collected during the summer of 1967, on dietary preferences and grazing patterns of elk in the northern Big Horn Mountains of Wyoming. Forest openings, where only elk grazing occurred, were studied to determine preferred plant species for both the spring and summer seasons.

One forest opening of approximately 300 acres was stratified to determine if there was a correlation between elk grazing patterns and distance from forest margin. Elk grazing patterns were found to be not correlated with distance from forest margin. However, there was a definite correlation between elk grazing patterns and percent total basal cover of herbaceous vegetation.

Data on diet preferences indicated that elk utilized grasses during the spring period but shifted their preference to forbs during the summer season. Preferred species for the spring period were *Bromus marginatus*, *Bromus* spp., *Festuca idahoensis*, and *Poa* spp. Preferred species for the summer period were *Agoseris glauca*, *Balsamorrhiza incana*, *Potentilla diversifolia*, and *Astragalus miser*.

Land Management Policy and Development of Ecological Concepts[1]

DONALD A. JAMESON[2]

Associate Professor of Range Science, College of Forestry and Natural Resources, Colorado State University, Fort Collins.

Highlight

As ecological concepts become incorporated into the training and background information of professional land managers, they also become incorporated into land management policies. Recent developments in ecology, such as nutrient cycling studies and computer simulation of complex processes, have a favorable climate for acceptance. Possible applications should be carefully studied by land managers.

It is certainly paradoxical that in a world filled with hunger, the United States is constantly faced with the need to hold back on agricultural production. It is also disturbing to many of us who have worked for years to increase livestock production on rangelands that our efforts in this direction, although desirable from an individual viewpoint, are no longer critical from the national viewpoint. It is particularly frustrating because we have the technology to double or perhaps triple the production from our rangelands. Because of these facts, range managers have, in many cases, lost their sense of mission.

There are, however, more and perhaps greater things which need doing. I like to classify the jobs facing range managers today into the categories of (1) scientific understanding of the resource, (2) technological efficiencies (as opposed to technological possibilities), and (3) rural social adjustments. This order is not intended to assign any priorities to these three tasks; all are deserving of full consideration. This paper, however, will deal only with scientific understanding of the resource.

Theories are basic tools of science; all scientists need theories on which and with which to operate. It matters little whether the theory is correct, it must, however, be useful. Consider, for example, earlier theories of electron flow. Much electronic equipment was first designed with the belief that electrons flow in a certain direction around a circuit. As it turns out, electrons actually flow in exactly the opposite direction; nevertheless, circuits based on the original theory do work. Many other examples of operable, but inaccurate, theories exist. A theory, therefore, is to be judged not on the basis of truth, but on the basis of its usefulness. As long as the theory is useful, it very likely will not be replaced, but when the theory is no longer useful, it will eventually be replaced. The emphasis in this paper, for example, is intended to be provocation rather than accuracy, and hopefully the paper will have a short life.

Ecological Concepts of Existing Policies

Some early theories of ecology were developed from observations on the peat bogs of Europe, where several observers felt that the bogs developed through well defined stages. This reasoning was perhaps most notably followed in the United States by Clements (1916), who with Weaver (Weaver and Clements, 1938) developed a strong school of successional ecology based largely on observations in the sandhills of Nebraska. Clementsian ecology became the focal point of U. S. ecology for many years, and certainly received much impetus from the very practical management needs that were pointed out during the "dust bowl" days of the 1930's. Clementsian ecology, and other viewpoints of successional ecology, propounds that we first begin with bare rock which is converted by stages. These stages may include lichens and mosses, annual plants, perennial forbs, grasses, and finally, in appropriate climates, shrubs or trees. Such a progression is known as a xerosere. On the other hand, hydroseres, beginning with water but ending with the same climax condition, also can occur. If the progression from rock or water to the climax community is set back by any disturbance, and progression is then allowed to resume, the resumption of succession is known as secondary succession.

Most land managers in the United States today who are in a position to make policy decisions were most likely trained in successional ecology. In fact, concepts of successional ecology have been written into policy statements of many land management and advisory agencies. In some agencies, Clementsian ecology has become so entrenched in service policy that any one speaking out against these concepts, or even offering additional concepts, is considered a heretic.

Theories of successional ecology certainly have been useful. It was, for example, a most useful and necessary tool to recover from some of the earlier abuses in range management in the western United States. Certainly in many areas we have a long way to go before we can completely exhaust the benefits from successional ecology and its concepts. We have, however, continued to use successional ecology

---

[1] Work presented in this paper was supported in part by National Science Foundation Grant GB-7824 for the Analysis of Structure and Function of Grassland Ecosystems. Many of the ideas expressed in this paper are the result of discussions with several of the investigators in the Grassland Biome subprogram of the International Biological Program, particularly L. J. Bledsoe and G. M. Van Dyne. Received January 23, 1970; accepted for publication May 8, 1970.

[2] The author is Director of the Pawnee Site project in the Grassland Biome program of the U.S. International Biological Program.

over and over until it has lost much of its usefulness. Much of the western range is in a condition where great progress from secondary succession alone cannot be expected. Most ranges are in much better condition than they were earlier, and we certainly have the necessary basic technology, if not the economic efficiency and political ability, to finish this particular job. In addition, Clementsian "sand hill" ecology has been pressed into use in areas where it was not conceived and where it is not quite so appropriate. Perhaps a few examples would be in order. In timbered lands, for instance, the progression towards climax does not necessarily equal a progression towards better conditions for range livestock. In fact, a climax coniferous forest is usually in very poor "range condition." On the other hand, a well established and well managed seeded range, by definition, is in a disclimax state because all of the species present are invaders, but, from the productivity standpoint, it may be excellent.

Although theories of successional ecology are still used by land management agencies, many range researchers have long since abandoned this concept as a fruitful area of research. They have, instead, turned to such fields as plant physiology, animal nutrition, and agronomy (including reseeding and brush control). This shift to similar, but more restricted, fields has, in part, been promoted by educational institutions which have been unable to offer solid training in range science as a total system concept. This search for meaningful research fields has led, in many cases, to fragmented research programs without a central theme, and has occasionally produced dichotomies between researchers and land managers.

Recent Trends in Ecology

Useful as successional ecology has been, it has become somewhat shop worn and is now being replaced on the theoretical front by a wide array of concepts and mathematical techniques and approaches collectively known as systems ecology. Since the term is used to describe a potpourri of the interesting and uninteresting, valid and invalid, and meaningful and meaningless, it would be impossible to cover systems ecology in a brief presentation. It is, however, possible to outline what seems a dominant concept as indicated by current interest of the scientific community, the probability of significant contributions of basic knowledge, and the validity of the use of the term systems ecology.

Tansley (1935) introduced the term "ecosystem" into the English language literature. Tansley's introduction of the term, however, was mostly a definition and it remained for Lindeman (1942) to clearly outline trophic (i.e., feeding level) ecology which has, in recent years, become a central theme for much ecological research. Lindeman happened to be an aquatic ecologist, and his paper on the trophic-dynamic aspects of ecology uses examples from aquatic communities. Nevertheless, the principles he outlined apply generally to other ecological systems.

Lindeman said that an ecosystem is a system made up of various compartments; the compartments are called trophic (feeding) levels and ordinarily include producers (or, more commonly, green plants), consumers (which in turn can be subdivided into primary consumers which eat plants, secondary consumers which eat primary consumers, etc.), and decomposers (which convert dead plant and animal matter back into carbon dioxide). Energy is received from the sun, and energy and matter are transferred among the various compartments. If we truly understood this transfer of energy and matter, we would then truly understand the operation of the system. If we understood these transfers so well that we could express them mathematically, we could then examine the effects of many manipulations of the ecosystem and predict many results without actually doing field experiments.

If we think about the few simple compartments outlined above (producers, consumers, and decomposers), we see that we could readily subdivide these compartments into growth forms, species, individuals, or parts of individuals. We could also consider many kinds of matter. Thus our concept of the ecosystem could very readily become entirely too complex to handle by ordinary bookkeeping systems. In addition, the measurements of transfers from one compartment to the other are in many cases quite difficult, and in Lindeman's time may have been impossible. In fact, many of them are still impossible, but introduction of radioisotopes as tracers and many sophisticated instruments have greatly facilitated and promoted studies of transfer processes.

For these very pragmatic reasons, therefore, trophic-dynamic ecology did not immediately arise to the forefront after Lindeman's original exposition. In fact, most of those attending universities over 20 years ago probably did not hear of trophic-dynamic ecology.

Modelling and Ecosystems

As noted above, when we subdivide the ecosystem compartments into the necessary functional complexity, the job of keeping track of the energy and matter flow among the various compartments soon becomes a major mathematical problem. Even for situations where the basic mathematical techniques are available very large problems could not adequately be handled until computers came into common use. At first computers were slow, large, and expensive to operate. As computers have become larger in capacity, they have also become generally smaller in size, faster in operation and, most important, much cheaper per job. Use of more complex techniques has become more and more feasible. More mathematicians, engineers, and now even biologists are becoming familiar with computer techniques. The development of mathematical tools used in analysis of feedback control systems is especially useful, and it it from this field particularly that much of the terminology of systems ecology is being drawn. An "adaptive control system with stochastic inputs" (Rosen, 1967), for example, sounds exactly like an ecological situation. The concept of an adaptive system, in fact, provides for union of the theories of successional ecology with the theories of trophic ecology if we consider an ecological system which is undergoing succession as a self-organized system (Margalef, 1968).

We now find arising today a considerable number of mathematically-oriented biologists, and biologically-oriented mathematicians and engineers, who are attacking the problem of trophic-dynamic ecology. It is something of a basic ground swell among ecologists. In fact, we can say with certainty that complex ecological systems will be investigated from the standpoint of trophic-dynamic ecology and systems engineering. The only question, since science does progress as a body, is who is going to do it best.

It happens that at the moment the primary worldwide research effort in this area is centered about the International Biological Program (IBP). Particularly in the U. S. these efforts are imbedded in the integrated IBP research program on the Analysis of Ecosystems (AOE). A number of IBP Biome programs have been organized within the AOE including the Grassland, Desert, Eastern Deciduous Forest, Western Coniferous Forest, Tundra, and Tropical Biomes. Of these biome programs, the Grassland was selected for the first major effort because of (i) its seeming simplicity, (ii) the location of a suitable intensive study area, namely the combined areas of the Pawnee National Grassland and the Central Plains Experimental Range, known in IBP circles as the Pawnee Site, (iii) the rapid and extensive cooperation of a suitable

from (time t) \ to (time t+Δt)	C_1 Live plants	C_2 Standing dead	C_3 Plant litter	C_4 Microflora	C_5 Soil Organic Matter	C_6 Herbivores	C_7 Omnivores	C_8 Carnivores	C_9 Soil fauna	C_{10} Animal litter
C_1 Live plants	-1	+	+	+	+	+	+	0	+	0
C_2 Standing dead	0	-1	+	+	+	+	+	0	0	0
C_3 Plant litter	0	0	-1	+	+	0	0	0	+	0
C_4 Microflora	0	0	0	-1	+	0	0	0	+	0
C_5 Soil Organic Matter	+	0	0	+	-1	0	0	0	+	0
C_6 Herbivores	0	0	0	0	+	-1	+	+	0	+
C_7 Omnivores	0	0	0	0	+	0	-1	+	0	+
C_8 Carnivores	0	0	0	0	+	0	+	-1	0	+
C_9 Soil fauna	0	0	0	+	+	0	+	+	-1	+
C_{10} Animal litter	0	0	0	+	+	0	0	0	+	-1

FIG. 1. A matrix of transfers between compartments of a closed system. Here, 0 = no transfers, -1 = diagonal elements, and $+$ = transfer between compartments. The sum of all positive numbers in the columns of this figure will be $+1$, so that for closed systems at steady state the total transfer to each compartment will sum to zero.

pool of scientific manpower available at the several major nearby universities and colleges and associated federal research organizations, and (iv) the obvious dependence of man on the grasslands of the world.

Matrix Representation of Ecosystems

We have stated above that an ecosystem is a system which transfers energy and matter from one compartment to another (for a further discussion see Margalef, 1968). If we have "n" such compartments, we can describe a greatly simplified ecosystem as a "$n \times n$," who-eats-whom matrix in which the elements of the matrix describe the rate of transfer of energy or matter from each compartment at time "t" to each of the compartments at time "$t + \Delta t$" (Fig. 1). If we knew the individual coefficients or mathematical functions for all such transfers in this matrix, we could then claim to understand the function of the ecosystem. In Fig. 1, I have entered some zero coefficients, but scientists involved in the study of various transfers will make the case that, in the strictest sense, there are very few zero transfers. At this point, however, the matrix is most important to point out an approach.

Ingestion of herbage by herbivores is one transfer process—in this case the transfer between live plants and a particular herbivore species. The rate of this transfer process becomes an element in our who-eats-whom matrix. Biologists have been working on the determination of many of these transfers for some time, but others have not received a great deal of attention. In fact most of the energy and matter transfers cannot be measured directly. Therefore if we are to say that we understand an ecosystem by knowing where energy and matter flows in the system, we must find some other procedure.

An Analytical Approach

An alternative is to determine the amount of energy and matter in each compartment at several points in time. With these data points in hand, we can arrive at a solution of the "n × n" matrix of coefficients which describes the flow of the matrix using solution techniques as outlined by Berman et al. (1962a and 1962b) and Bledsoe and Van Dyne (1968).

To facilitate solution we can utilize any knowledge we have concerning transfers, that is, we can provide constraints for the elements of the matrix. For the most part we may guess the zero or near zero coefficients from past experience. These analyses give us our first approximation which is a linear, constant-coefficient model. Additional information is required to develop more realistic nonlinear models, which we have every reason to expect will be required to describe real world events. The same basic analytical procedure, however, can approximate nonlinearities and discontinuities through linear segments (Bellman and Roth, 1966).

With such a model in hand, various forms of sensitivity analyses can be made. One can investigate stage by stage the effect of modifying the system; i.e., one can change a coefficient of the model to determine the overall effect on the compartments many stages later.

Spatial Relationships

The matrix presented in Fig. 1 represents changes in time. In trophic-dynamic ecology, point space is usually assumed. If we expanded the matrix in a third dimension representing spatial distributions we would then have a representation which would cover various areas. People other than mathematicians ordinarily consider a space as being distributed; that is, from any point to any other point it is possible to be at any intermediate location. The mathematics of such a system, however, become quite complex. It would be much easier mathematically to consider space as lumped so that pastures, soil mapping units, etc., become discrete units.

Open Systems

We can consider two forms of constant coefficient models—a "closed" form and an "open" form. These mathematical properties also have important relationships to biological problems. A system can be considered "closed" if we can actually measure all compartments. If we are unable to measure the amount of matter or energy in any of the compartments, the system is "open" and we will not be able to obtain a direct solution from the method presented above; therefore we must have a measure of all transfers to and from compartments which we cannot measure directly. In other words, we must measure all input to and output from our otherwise closed system.

On many semi-arid rangelands we have reason to believe that because of low fixation and low loss rates it may be possible to approach the study of nitrogen transfer by a closed system approach with only minor errors. We know, however, that carbon cycling and energy transfers must be considered an open system. A knowledge of the carbon dioxide fixation rate through photosynthesis studies then becomes an important part of a total systems study. In addition, losses of carbon and energy from the food chain require studies of plant and animal metabolism, and losses of soil moisture require studies of evapotranspiration to elucidate losses from the various compartments to the outside atmosphere.

Forcing Functions

In ecology, the text by Daubenmire (1947) represents the study of the effects of environmental forces on components of the ecosystem. In the language of systems engineering, such outside forces which cause changes in the system are called forcing functions. The time required for the system to return to "normal" after it has been influenced by some outside force is called transient time and the "normal" situation is called the steady state. By analyses of the output of a system when forced or perturbated with a known input, we are able to determine the transfer function of the system, which is the ratio of the output to the input. Once we determine the transfer functions of the system, we can build a system simulator and replace these standardized inputs with the variable forcing functions which occur in nature, and observe the system behavior under these conditions. Such concepts have been widely and profitably used in some fields of biology (Milsum, 1966) but have not been commonly used in ecology.

In rangeland ecosystems highly probabilistic rainfall is the chief perturbation or cause of noise. A better behaved forcing function is solar energy. We have been hampered a great deal in the past by the fact that climatologists prefer to express their data in terms of some sort of averages. Weather, however, is not average, but probabilistically variable, i.e., stochastic, and in a study of the effect of forcing functions on the operation of the ecosystem we need to describe climate by the parameters which point out these probabilistic properties. There are various ways to represent climate by the characteristics which determine its variability so that it can be used in computer simulation (e.g., Pattison, 1965), but we will not go into these methods here.

In the past few paragraphs I have described an approach which represents mathematically the function of a range ecosystem. The core of this approach begins with the constant-coefficient closed system which is represented in the "n × n" matrix of constant transfers between "n" compartments. This basic system was first expanded to include spatial relationships, further expanded to allow inputs from outside the system primarily in the form of carbon dioxide fixation, and outputs from the system primarily in the form of carbon dioxide release and evapotranspiration. Such a system would become quite stable were it not for such influences as rainfall and solar energy, which shock the system out of its steady state.

System Behavior

How do such systems behave? For many range ecosystems manipulation of grazing animals causes a significant change in the nature of the producer compartment of the ecosystem. This impact of grazing on range plants has, of course, been the central theme of range management. If we had a study area, however, which has reached some equilibrium with grazing, the year to year changes can be considered to be random events. The annual values in a purely cyclic system show no change and are not particularly useful for systems analysis. There are, however, changes within years. This points out that in the study of an ecosystem which is relatively stable we can probably learn more by a study of seasonal rather than annual effects.

The seasonal changes in any population, regardless of how complex they may be, can be represented to any arbitrary accuracy by a series of sine and cosine terms. Such equations, although they can describe the behavior of a system, do not help show how it works. As we learn more about the system we are able to develop more mechanistic models; that is, we are able to predict more and more precisely the response to various inputs, add terms to the equations describing system behavior as a function of these inputs, and delete terms showing responses as a function of time.

Models and Simulators

We have progressed from a rather simple constant-coefficient, closed system model to a spatially disturbed, nonlinear, open system with random environmental effects and system responses which are functions of probabilistic inputs. This build up from simple to complex models has been a most useful approach in systems analysis and simulation in many fields. For example, Forrester (1961) observed:

> "In engineering systems models have been built upward from available knowledge about separate components. Designing a system model upward from identifiable and observable pieces is a sound procedure with a history of success.
>
> In economics, models have often been constructed working backward from observed total systems results. Even as a theoretical goal, there is no evident reason to believe that the inverse process of going from total-system behavior to the characteristics of the parts is possible in the kinds of complicated, noisy systems that are encountered. . . ."

Computer simulations of a great number of biological phenomena are becoming more and more common, and proper use of simulation techniques can be very effective in resource management planning. An example in range management is the work of Goodall (1969). Examples of several simulators in other fields are cited by Watt (1966, 1968).

Simulators and other models are useful in organizing and describing existing knowledge about a particular system, and point out areas where new studies are needed. They may include analytical techniques such as described in this paper or techniques borrowed from business and economics (e.g., Hein, 1967), but generally are built from many simple relationships, utilizing knowledge and concepts of individuals or teams of individuals who are thoroughly experienced in a particular area. In short, useful simulators are built not so much from complex techniques as they are from experience and hard work.

New Land Use Policies and Research Possibilities

In the beginning of this paper I stated that successional ecology has, in the past, been so useful in range management that it has, in fact, become embedded in the policy of land management agencies. Whether or not trophic-dynamic ecology can be utilized in resource management to the same degree remains to be seen. I have observed, however, that not only ranchers but city dwellers as well seem to be able to understand the basic concepts of trophic-dynamic ecology much more easily than those of successional ecology, and it appears from the public and congressional support of the IBP that trophic-dynamic ecology can be a program which is much easier to "sell" than successional ecology. Nevertheless, much of our background information is in terms of successional theories, and to make greatest use of this information we should seek integration of the various schools of thought.

Several years ago a prominent Southwestern rancher asked if there wasn't some way to include new ideas, such as energy flow studies, in range research programs. Certainly ranchers are extremely interested in how much energy and matter flows from the producer compartments to the large herbivore compartments, much more so that they are in the successional stage of a particular range, and we all are concerned about how our technological disturbances of some compartments of the ecosystem may influence other compartments of the ecosystem in which we live. In addition, properly formulated and operating models of trophic-dynamic and other systems allow us to explore many land management alternatives without actually applying treatments in the field. This could be an extremely valuable tool.

At the moment we are not prepared to incorporate large pieces of trophic-dynamic ecology into land management agencies' policies, particularly since the first attempts to be realistically complex in such investigations are just now beginning. I think it is appropriate for land managers, both public and private, to encourage research in new aspects of ecology and to begin to explore new ways which these modern concepts can be incorporated into land management guidelines.

As in any new field there will be many false starts and inefficiencies.

Obviously the skills required soon exceed the abilities of any one individual, and team research is required. An ideal institution for such complex research would have flexibility and access to a wide variety of individual specialties, and at the same time a critical mass of interdisciplinarians with dedication to, and time for, the necessary integration between the various specialties. Large universities (or several nearby universities) and their associated federal research organizations do have a wide variety of intellectual skills, although we are finding that in certain specialty areas people do not exist even in five universities. This complex effort, however, requires new concepts in integration, unity of purpose, continuity of personnel, and administrative efficiency which previously have not been universal attributes of universities. We find that necessary structure and teamwork can be developed once the individuals concerned become convinced of the urgency of the problems and the benefits of cooperative research.

The payoff from such research could be great, or, like any research, the direct payoff in terms of applied management practices could be nil. It appears very probable, however, that investigations into new concepts of ecology will more likely be profitable than many things which we have done in the past in rangeland research and will provide a basis for rational resource decisions in the future.

Literature Cited

Bellman, R., and R. S. Roth. 1966. Segmental differential approximation and biological systems: An analysis of a metabolic process. J. Theoret. Biol. 11:168–176.

Berman, M., M. F. Weiss, and E. Shahn. 1962a. The routine fitting of kinetic data to models. A mathematical formalism for digital computers. Biophys. J. 2:275–287.

Berman, M., M. F. Weiss, and E. Shahn. 1962b. Some formal approaches to the analysis of kinetic data in terms of linear compartmental systems. Biophys. J. 2:289–316.

Bledsoe, L. J., and G. M. Van Dyne. 1968. Evaluation of a digital computer method for analysis of compartmental models of ecological systems. Oak Ridge Nat. Lab. TM-2414.

Clements, F. E. 1916. Plant succession: an analysis of the development of vegetation. Carnegie Inst. Pub., Washington, 242:1–512.

Daubenmire, R. F. 1947. Plants and environment. John Wiley and Sons, Inc., New York. 424 p.

Forrester, J. W. 1961. Industrial dynamics. The M.I.T. Press. 464 p.

Goodall, D. W. 1969. Simulating the grazing situation. *In* F. Heinmets [ed.] Concepts and models of biomathematics: Simulation techniques and methods. Marcel Dekker, Inc.

Hein, L. W. 1967. The quantitative approach to managerial decisions. Prentice-Hall. Englewood Cliffs, N.J. 386 p.

Lindeman, R. L. 1942. The trophic-dynamic aspect of ecology. Ecology 23:399–418.

Margalef, R. 1968. Perspectives in ecological theory. The Univ. Chicago Press. 111 p.

Milsum, J. H. 1966. Biological control systems analysis. McGraw Hill. N.Y. 466 p.

Odum, E. P. 1959. Fundamentals of ecology. 2nd Ed. W. B. Saunders Co. 546 p.

Pattison, A. 1965. Synthesis of hourly rainfall data. Water Resources Res. 1:489–498.

Rosen, R. 1967. Optimality principles in biology. Butterworths, London. 198 p.

Smith, R. L. 1966. Ecology and field biology. Harper and Row. N.Y. 686 p.

Tansley, A. G. 1935. The use and abuse of vegetational concepts and terms. Ecology 16:284–307.

Watt, K. E. F. 1966. Systems analysis in ecology. Academic Press. N.Y. 276 p.

Watt, K. E. F. 1968. Ecology and resource management. McGraw-Hill. N.Y. 450 p.

Weaver, J. E., and F. E. Clements. 1938. Plant ecology. McGraw-Hill. N.Y. 601 p.

THESIS: UNIVERSITY OF WYOMING

Preference and Utilization Trends by Cattle on Grass–Forb Vegetation in the Northern Big Horn Mountains, Wyoming, by Lynn D. Todd. M.S. Range Management, 1969.

Vegetative preference and trend of utilization shown by cattle on the northern Big Horn Mountains of Wyoming was measured during the summer of 1968.

Two study areas were selected. The first was at an average elevation of approximately 8,600 feet while the second was at an average elevation of 9,300 feet.

The livestock preferred grasses and sedges over forbs. The major preferred grasses and grasslike plants were *Agropyron* spp., *Koeleria cristata, Poa* spp., *Stipa* spp., and *Carex* spp. The major preferred forbs were *Taraxacum officinale, Agoseris glauca, Polygonum bistortoides,* and *Arnica* spp. There was some difference in preference shown for forbs between the two elevational sites.

Some degree of utilization trend was shown for most species. The most definite and most explainable trends were found to be in forbs. Utilization trend in grasses and sedges were not as explicit.

Range Management in the Developing Countries[1]

LINNEO N. CORTI

Livestock Consultant, Rome, Italy.

Highlight

Programs for developing countries involve considerations of anthropology, sociology, education, and general planning, as well as the usual sciences basic to range management. The program should include 3 different phases that consider: a) evaluation of the resources, the people, and their cultural, social, and economic interests; b) training and feasibility studies; and c) implementation and technical assistant.

In the U.S. and in the developed countries "Range Management" means essentially the adoption of specific techniques for maximizing the productivity of grazing lands.

It is a science because it relies upon climatology, geology and pedology, botany, animal physiology and genetics, and lastly, on economics. It is an art because, in the combination of so many sciences, experience and individual capacity plays an essential role.

Such an approach is accepted by every modern stockbreeder, who would readily apply any sound technical and economic advise aiming at "maximizing the productivity of grazing lands."

But is this really so in the great pastoral areas of the underdeveloped countries? I have in mind here the Middle East from Iran to Iraq, to Saudi Arabia, to North Africa—all along and south of the narrow strip of cultivated land on the shore of the Mediterranean down to the Sahara—to the Sahel and Sudan belts of West Africa, to many areas of East Africa—the pastoral zones of Ethiopia, etc.—all countries of which I have experience.

I am convinced that in these areas range management should mean something more, and would therefore require a different and somewhat more complex approach: we would certainly add anthropology, sociology, education, and general planning to the list of sciences involved. Human implications are so important there, and the evaluation of the development periods so essential that, without the aid of these sciences, any program of range management based on purely technical assumptions is bound to fail.

The comprehension of the herdsmen's behaviors and attitudes is not an academic approach, but permits an assessment to be made of the positive contribution they can make to the objectives of the projects in which they are involved.

In many cases it would even be of great value to investigate in depth the psychology of the herdsmen, so as to understand which are the moving forces that determine their fundamental behaviors. But, nearer the surface of the problems, one should always understand their attitude towards management.

In the developed countries, for a rancher, livestock breeding and, therefore, range management has an essential goal: profit. It is not the sole aim, but is the fundamental one. In the countries I have referred to, and probably also in others, pastoralists are even today still seeking security and survival.

Most of the pastoral areas are located in arid or semi-arid zones, where rainfall is low, strictly seasonal, and where periods of drought are frequent and often pluriannual.

The life of the flocks of sheep and goats and the herds of camels and cattle as well as the stockbreeder's income are strictly correlated with the climatic variations, but the effective income—the amount of money available for satisfying the needs of the family—does not vary as much as is generally thought.

In fact, when rainfall is poor the crop of lambs, kids, and calves is small and there is little milk: the income will therefore be low. If the drought persists the breeding-stock will shrink and the newly born animals will be insufficient to replace the old ones. If the breeder sells some of his stock, it will be for buying food for the animals, which will be filled up with dry matter without their nutritional requirements being met.

At this time part of his income will come from realizing part of his capital, while in the same time, inputs will grow. This is also the period in which the breeder gets into debt.

At the end of the drought, the animals left will be in poor condition and their number reduced. When rainfall comes at last, everything seems to rejoice: very often desert animals have an extraordinary capacity for regaining their weight and for reproduction as soon as the vegetation starts a new growth. But the stockbreeder has to rebuild his stock; all newly-born females will have to be raised for this purpose and production will be low because the breeding stock is reduced in number and many sales of slaughter animals, wool, hair, and animal-ghee will go to pay off the debts. Accordingly, in this period also the real income will be small.

The only policy the stockbreeder can conceive is to maintain the maximum possible number of animals, hoping that most of them will survive the drought.

Another important reason which dictates the same policy is the high incidence of infectious diseases and of internal and external parasites. In spite of the application of veterinary measures in many countries, the loss from animal diseases is high and for the majority of the stockbreeders the only way to overcome this problem is still to main-

[1] Presented at the annual meeting of the American Society of Range Management, Denver, Colorado, February 1970. Accepted for publication February 13, 1970.

tain a great number of animals, with the hope, here too, that the majority of them will survive.

In this situation there is no place for a real concept of profit-making and for what we mean by management capacities, and consequently for the development of needs which are not strictly connected with subsistance and survival.

That is why all measures, which seem realistic, such as the selling of old and crippled animals and young stock, so as to avoid depletion of ranges in drought periods, are not accepted.

The stockbreeder is suspicious towards such measures, firstly because without Government aid to support prices, he will make very little money; secondly because when vegetation growth starts again, he will not be in a position to buy fresh animals.

He will also accept reluctantly the idea of feeding his breeding stock with reserve feeds until the range improves, for the fear of being unable to provide for family needs and of running into debt; debts are a tragedy because usurious interests are always charged. He will be compelled to buy feed for his animals but never in sufficient quantity to maintain production and reproduction at normal standards.

For him also, the financing and setting-up of a farm for producing reserve feeds is a remote possibility, for lack of capital and also of technical ability.

It is certain that lack of capital, of technical know-how, and of management capacities hamper the development of the pastoralist enterprise, but to what extent this is due to primitiveness and not to a logical response to an adverse environment should always be understood.

What should be stressed is the principle that all the reasons which underlie the behaviors and attitudes of the pastoralists should be made clear before suggesting new solutions. This approach is generally of great help in choosing the measures that can lead to a consolidated sence of security, which must be considered the first fundamental step towards a more positive and managerial—in a modern sense of the word—attitude.

Great attention should be given also to the character of the pastoralist society. All the traditional forms of social organization are also built for security.

If one observes the fundamental characteristics of pastoralist societies, it appears clear that all of them are based on the same structure: the tribe.

There is a large amount of literature on this subject, but very often one is concerned with a sort of archeological anthropology and sociology: great importance is given to cultural aspects, but little to the basic reasons which have led to the fundamental structure of the tribe.

The tribe, from the qabila of the Arabian countries, to the Taifé of Persia, and to the Kedo of the 'Afar of Ethiopia, was and still is to a large extent, the most logical socioeconomic organization of the pastoralist.

The tribal system permitted:

a) the assignment, to each tribe and to each specific group of the tribe, of a determined area of grazing land and the right to water the animals at given water points.
   This matter was usually governed by well determined rules. These rules also made an exception, in the Muslim Countries, to the precept of the Koran which makes grazing resources and water free to everybody;
b) the possibility of establishing alliances and agreements between the tribes for the migration into the respective tribal territories in given periods of drought, when the pastures were too poor for grazing;
c) prompt defense against enemies or sudden attack to conquer new lands, when the weakness of other tribes allowed, or also, to raid passing caravans.

The tribe was generally seen as an autocratic organization, ruled despotically by its chiefs. On the contrary, very often, it was a democratic organization because power derived, through the different sections and sub-sections, from the will and the agreement of the majority of its members. And, also, if the leaders generally inherited their title to rule from their ancestors, they had to prove, as was the case in Arabia, they were loyal, brave, and hospitable; if not they could lose their right.

Certainly the struggle to survive in a harsh environment like the pastoral areas would have been impossible on the basis of a simple familistic conception which would have led to anarchy and disorder.

But what must be noted and stressed is that the tribal organization permitted in some way the best utilization of the grazing resources and a sort of primitive range management in the sense that each group of pastoralists was aware of the necessity of preserving his resources from over-stocking. I do not want to overstress this point because the effects of overgrazing and tree cutting from time immemorial are so evident in many grazing areas; however, I feel that this feeling of defending their resources was always a main concern of the pastoralists.

There are also astonishing examples of proper range management like the "hema" institution of Arabia, which dictates strict rules for the use of natural vegetation in the areas surrounding the villages, to obtain the highest yields. Some rules dictated the total exclosure from animals of some zones, to be kept only for the benefit of bees!

With the birth of the national states, the tribal institutions entered a more or less open conflict with the forces who were planning national unity and were building-up a centralized administration. All the efforts of the state were directed towards the elimination of local power and disparities, for the application of principles of equality. In this direction for instance many governments have declared that the grazing lands should be considered public and free to everybody.

Governments did their best—and are still doing so—to break down the tribal organization which has been always considered a centrifugal force against national unity. The newly-born states had to fear the influence and power of the tribes, who were very often well equipped with arms, jealous of their independence and of their own rules, and unwilling to become subject to a centralized power which could only mean a constraint to their freedom and probably the arrival of tax collectors.

The newly-born states have meant also development and specialization of agriculture and an accentuation of the struggle between farmers and stockbreeders: the settled farmers no longer accept the leadership of the nomads and they are unwilling to permit grazing on stubble and fallow lands.

Mainly for these reasons, many governments have a policy for the settlement of pastoralists: results are different between the various countries, according to the character of the groups involved and the soundness of the settlement schemes.

In general the results are meager: certainly the schemes often fail through lack of facilities and technical assistance. All in all, the problem of pastoralism is still largely unsolved in many countries, and many of these groups are often pushed aside from the new social categories and classes which are being created.

There is no sense in defending the tribal system as a whole, even if it is a fascinating world which is bound to disappear; but at the same time what is still vital in it should be saved: the capacity to organize life in a harsh environment, the feeling of solidarity between the members of the group, the readiness to accept discipline if it is within the framework of the regulated life of the group: all these are positive attitudes that can help enormously in the reorganization of pastoralism in new and stabilized forms.

All this should be clear to those who are called upon to implement range management programs.

Also the schemes for education should be studied case by case and not generalized because behaviors and attitudes are often quite different from one situation to another. They should start from an attentive study of human and social aspects.

Planning of range management projects and programs in the developing countries should be first examined in the light of the lines of each country's general development. There are situations of great misery that should be eliminated: the Bedouins who still live with their camels in the Empty Quarter of Arabia should be helped to move away, as soon as the state can provide alternatives for them.

When it is clear that there is a reason for implementing the program, the adopted approach should be global. All measures should be strictly integrated so as to maximize the effect of each one.

We should no longer see separate measures such as the drilling of new wells without a contemporary range-use program, or the implementation of veterinary services for animals which cannot be properly fed: all this leads to overstocking and therefore to depletion of fundamental range resources.

The measures should start from the evaluation of the resources and go up to man, to his cultural, social, and economic interests.

Schematically, the measures may be divided into 3 different phases.

The first phase should comprise:

a) Inventory of grazing resources, with assessment of range-potential and range-condition. The maps of the range-units or sites should be at an operational scale.
b) Inventory of land and water which can be utilized for the production of reserve feeds.
c) Study of the pastoralist population, their behaviors and attitudes, their social organization, the actual range-use practices, and the economic situation.
d) Market study for animal products.

The second phase should comprise:

e) Staff training of personnel. Trainees for "Rangers" should be selected from young men coming from the pastoralist population.
   These young men already have very often a good knowledge of the environment in which they will be called upon to work and are familiar with the customs of their people and with life on the range. They must be given basic scientific knowledge to enable them to understand the nature of familiar occurrences, and must be trained in the techniques they will have to apply.
f) Feasibility studies concerning the setting-up of farms for the production of reserve feeds and other necessary facilities: slaughter houses, cold storage, dairies, plants for processing wool, hair, hides, skins, slaughter-house wastes, etc.

The third phase could comprise:

g) Construction of farms and facilities.
h) Creation of range management technical and financial services.
i) Implementation of all other services: adult education, schools for children, medical assistance, etc.

A Grazing Potential in the Tanga Region of Tanzania[1]

E. G. VAN VOORTHUIZEN[2]

Pasture and Range Research Officer, Near East Foundation—U.S. AID/Government of Tanzania, Arusha, Tanzania.

Highlight

The steady decline in the sisal market has resulted in greater emphasis on raising of livestock from sisal areas and from native rangelands in Tanzania. Livestock production in many areas of Tanzania is limited by Tsetse fly (*Glossina pallidipes*). However, in large blocks of land cleared for sisal production, Tsetse, which breeds in dense bushlands is now a minor problem. Proper planning for uniform utilization and maximum sustained production from rangelands are based on local experience and experimental data. In the Tanga Region of Tanzania experimental data for proper planning is lacking. This article presents the results from a range site survey and estimation of the livestock production capacity in the sisal areas of the Tanga Region. Also, the report emphasizes the need for more detailed studies.

The Tanga Region of Tanzania has approximately 13,700 square miles of high potential bushed-grassland, of which 500 were cleared for sisal production and 550 are in the Mkomazi Game Park.

Precipitation occurs from March–May and from October–November. The hottest months are December, January, and February and the coolest are June, July, and August. In the northern part of the region, the Usambara Mountain Range rises from the coastal belt in a northwest direction and continues as the Pare Mountains to Mt. Kilimanjaro. The Usambara serve as a watershed for the Umba River to the north and east and the Pangani River to the south and east (Fig. 1). In the southern part of the region the coastal belt is succeeded by hills, then undulating country at 1500–2000 feet elevation. The Msangasi River is the major drainage in this area.

Due to social problems related to prestige, religion, and culture, beef production at present is almost entirely extensive with low outputs and low inputs. The traditional method of cattle management consists of grazing unenclosed common natural pasture, the cattle being tended in combined herds by members of the family and returned in the early evening to a small enclosure or "boma." As a result, the surroundings of village settlements are much overgrazed while other areas are not used. Bomas become very muddy and unhygienic and frequently cattle are not released until long after sunrise and returned well before sunset, thus restricting their grazing time. Research work at Kongwa, Tanzania by Owen (1968) has shown that immature Zebu cattle grazing 24 hours per day grow up to 26% faster than do animals confined to a boma at night. In a considerable area of Tanzania there is an urgent need to intensify and develop settled systems of agriculture capable of providing adequately for the increasing population. The sisal areas in Tanzania have an important role to play in this development as a grazing resource.

Method

Grass–legume plant associations were recorded and mapped along bush trails, from aerial photographs, and by airplane reconnaissance. This information was recorded on a 1:250,000 scale topographical map and later reduced to a smaller scale of 1:1,000,000 for publication. Using a step-point method, paced

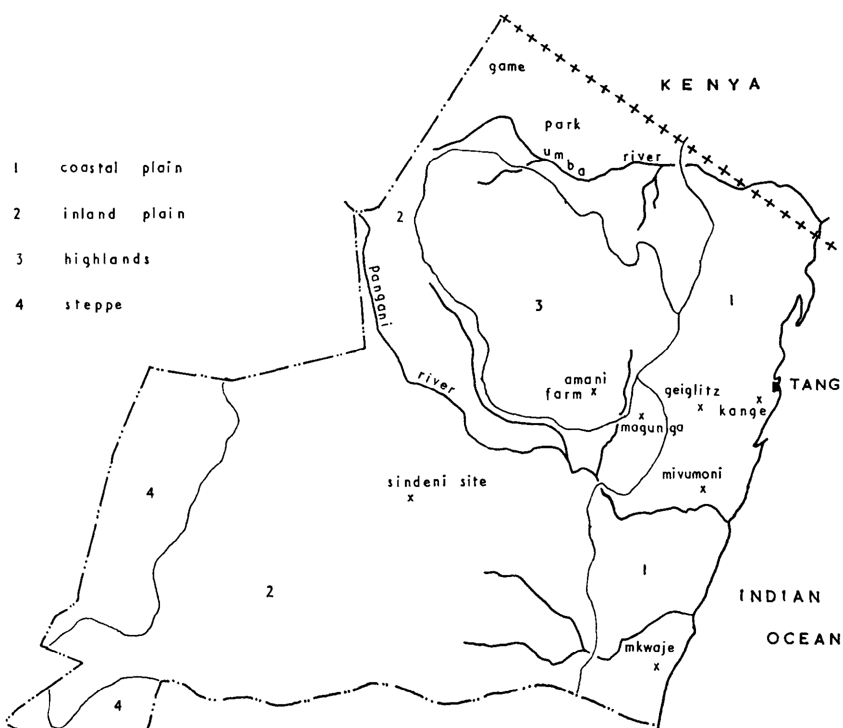


FIG. 1. Range sites in the Tanga region.

[1] Received September 17, 1969; accepted for publication January 12, 1970.

[2] The author wishes to acknowledge the assistance received from Dr. L. White for suggestions and encouragement, and the author is grateful to the Director of Research, Tanzania and the Near East Foundation, New York, N.Y. for permission to publish.

Table 1. Composition (%) of the major grasses on the Coastal Plain at 6 locations sampled.

	Geiglitz	Kange	Mivumoni	Maranzara	Mayomboni	Pangani
Andropogon schirensis		4	9		23	14
Bothriochloa glabra	2		13		6	4
Cynodon dactylon	26	2		2	4	7
Digitaria mombasana		6		7	4	3
Eragrostis superba	6		1		3	
Heteropogon contortus		1	14	1		2
Hyparrhenia dissoluta		15		10	18	22
Hyparrhenia rufa	19	11	9	7	14	14
Panicum infestum		16	2	15		
Panicum maximum	18					3
Panicum trichocladum			6	1	1	1
Pennisetum polystachion		2		6		5
Setaria sphacelata		39		30		1
Other grasses	28	2	46	21	22	17
Legumes	1	2			5	7

transects were run in representative site locations to measure the percentage composition by number. This was done by actual count and recording of the number of individuals of all forage species present. In addition, composition and range condition surveys were conducted on the Mayomboni, Gezani, Maranzara, and Amani-Marangu cattle/coconut schemes; the Mkwaje Ranch (Amboni Sisal Estates Ltd.), the Mivumoni Ranch, and the Tanzania Sisal Corporation ranches at Magunga, Geiglitz, and Kange. The reports are on file at the Mlingano Sisal Research Station, Tanga, Tanzania.

Six transect data, representative of the coastal plain are summarized in Table 1 and six transect data, representative of the inland plain are summarized in Table 2. The Mkomazi Game Park, although a potential grazing resource is designated as a wilderness area. In order to protect the game and to preserve the park as a wilderness, the Wakwavi tribesmen with their cattle herds are being located elsewhere. The park was not surveyed.

Result and Discussion

Four range sites were readily distinguished from the surveys:

1. The Coastal Plain—a low elevation, high rainfall area.
2. The Inland Plain—a high elevation, low rainfall area.
3. The Usambara Highland—a high elevation, high rainfall area.
4. The Masai Steppe—a low rainfall area.

The Coastal Plain

The Coastal Plain is bounded on the west by a distinct scarp and on east by the Indian Ocean. It is characterized by high humidity and high rainfall (40–60 inches annually). Temperatures range from 75–90 F. The plain extends inland about 20 miles rising to an elevation of 500 feet. The soils are loamy sands.

Hyparrhenia rufa, Setaria sphacelata, Hyparrhenia dissoluta, and *Andropogon schirensis* are the major grasses in the area (Table 1). Associated species include *Cynodon dactylon, Panicum infestum, Digitaria mombasana,* and *Bothriochloa glabra.* The marshy swamps along the Pangani River delta contain concentrations of *Imperata cylindrica,* a tough grass of low palatability, *Paspalum scrobiculatum, Echinochloa haploclada,* and *Echinochloa pyramidalis.* The abundance of naturally occurring legume forage plants such as *Stylosanthes fruticosa* is a significant feature of the coastal plain. Other legume plants include *Vigna reticulata, Vigna dekindtiana, Teramnes labiales, Eriosema glomerata, Dolichos argenteus, Alysicarpus glumaceus, Glycine javanica,* and *Clitoria ternatea.* These contribute

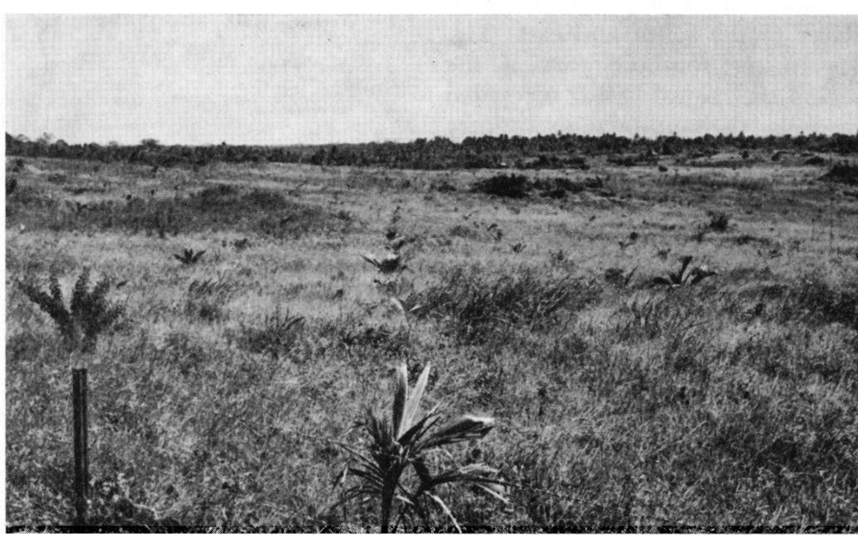


FIG. 2. Young coconut grove allowing ample forage production for cattle grazing.

Table 2. Composition (%) of the major grasses on the Inland Plain at 6 locations sampled.

	Handeni	Korogwe	Mabanda	Madera	Magunga	Sindeni
Bothriochloa insculpta			15	4		
Cynodon dactylon		14	3	19	9	2
Digitaria milanjiana	11	12	2	22		
Eragrostis superba	3	5	12	4		
Heteropogon contortus				2		
Hyparrhenia dissoluta	5		2			
Hyparrhenia rufa	6		11		19	
Panicum mezianum	3		6			
Panicum maximum	16	2		31	24	94
Panicum trichocladum	3				5	
Pennisetum polystachion	1					
Setaria sphacelata	12					
Themeda triandra		21				
Other grasses	39	46	49	17	42	2
Legumes	1			1	1	2

considerably to the improvement of the forage quality for livestock.

Near village settlements, coconut palms are often found in cultivated rows 30 feet apart allowing ample forage production for cattle grazing in coconut groves (Fig. 2). Where cultivation is not practiced, bush infestation drastically reduces forage production. Dumpalm (*Hyphaene thebaica*) is prevalent throughout the coastal plain, while *Acacia zanzibarica* dominates the southern part of the region.

Management problems

Bush control is a major problem in the coastal plains area, especially thicket forming *Acacia* species and the dumpalm. Grass burning to reduce bush density as it is practiced by the local people is only effective with an intense hot burn. This is accomplished when the grass cover is left ungrazed for at least a year to provide maximum burnable material. Although this is an economic way to reduce bush, the practice lowers the grazing capacity. With improved management and increased grazing intensity, the loss of forage from repeated burning to control bush is not justified. Mechanical methods are more feasible in controlling bush. The management of the Tanzania Sisal Corporation at Geiglitz (Stevens, 1969) has found that the initial clearing of shrub-type bush can be done effectively with a D-8 type Caterpillar tractor pulling a heavy duty Marden L-10 brush cutter at the cost of Sh.44/- (44 shillings) per acre. This must be followed up by stacking and burning using hand labor at Sh.24/- per acre. From then on the fields can be maintained with an occasional run of a farm tractor and rotary mower at a cost of Sh.4/- per acre annually. Adoption of such expensive practices requires good management to insure adequate returns on the investment.

Grazing capacity

The *Hyparrhenia* grass associations are not difficult to manage with proper numbers and distribution of livestock. The annual rainfall insures a continuous forage supply, although quality varies. It is indeed extremely rare when there is no rainfall recorded for any one month even during the dry seasons. Forage production from *Hyparrhenia rufa* in pure stands was estimated from clippings at 4400 lb. per acre. A pure stand of *Setaria sphacelata* yielded 3880 lb. per acre. Since there is a tremendous variability in forage production from year to year and a conservative stocking rate may mean overgrazing in successive dry years, stocking rates based on yields must be used as a guide only. It would be advisable to use utilization surveys in determining actual carrying capacity for each growing season.

At the Mkwaje Ranch, experience shows that 8 acres will carry 1 animal unit yearlong and this figure can be used as a starting point for other areas in the coastal plain.

The Inland Plain

The Inland Plain area is bounded on the west by the Masai Steppe and the Usambara Mountain Range to the north. The further inland the greater extremes in day and night temperatures and lower humidity. Rainfall becomes progressively lower moving inland to the dry and sparsely populated Masai Steppe. The average annual rainfall is 25–35 inches.

The soils are a red sandy loam with Guinea grass (*Panicum maximum*) the dominant species (Table 2) and occasionally found in pure stands (Fig. 3). Van Rensburg (1949) reported that Guinea grass is abundant in shaded areas where it is quite robust providing an abundance of flammable material in the dry season. Also it is remarkably tolerant to burning and thrives in areas which are periodically subjected to fierce fires. It recovers quickly from burning and will become established as the dominant species where burning is practiced. Associated species in the drier areas are *Cynodon dactylon*, *Digitaria milanjiana*, *Hyparrhenia rufa*, and *Eragrostis superba*. Legume plants are not so abundant as in the higher rainfall areas but *Dolichos taubertii* and *Glycine javanica* are common. Other species such as *Vigna vexil-*

FIG. 3. Pure stand of Guinea grass at the Sindeni site location.

lata, *Vigna fragrans*, and *Dolichos argenteus* are less frequently found.

One aspect which is often overlooked is the utilization of indigenous leguminous species and other browse trees by stock particularly in the semi-arid regions. Van Rensburg (1948) lists some of the more important species indigenous to East Africa many of which occur in the inland plain. *Acacia albida*, *A. benthamii*, *A. spirocarpa*, and others yield heavily of leaves and pods which are relished by stock during the dry season.

Management problems

Most sisal estates have developed in the Pangani River Basin and near transportation routes for easy access to the coast. The undeveloped wooded areas are difficult to clear because of the larger size bush-type and frequent thickets. Also, the production of livestock is hindered by the increased Tsetse fly problem, which may explain the low cattle populations in the area. Prophylactic drugs would be required to maintain proper animal health to reduce losses from Tsetse. Tsetse fly breeds in dense bush cover, and where areas have been cleared of bush, the incidence of Tsetse is markedly reduced. Bush control therefore must be considered a major management concern (Fig. 4).

Naveh (1966) cautions that we do not know enough about the importance of trees and shrubs possibly in recycling of nutrients from the subsoil and that indiscriminate bush eradication must be avoided. The object of the removal of undesirable plants must remain the creation of a stable bush–grass ecosystem. One solution will be to confine bush clearing to removal of thickets.

Bentley (1963) claims that hand-clearing methods in control of bush are adapted to the tree–shrub types, but it is too expensive for thicket types. Mechanical treatments are the only proven means for opening up thicket types that are too dense for hand clearing or for successful burning. For mechanical clearing of excessive tree growth two operations are needed. One to chain the area, requiring two D-8 size tractors and followed by a D-8 pulling a Marden brush cutter. This is needed because during chaining the smaller thorntrees bend under the chain and then spring back to their original position. Considerable hand clearing and burning must then take place to make the area suitable for grazing. This requires an initial outlay of approximately Sh.110/- per acre to become operational. The present low level of returns from livestock restricts such expenditures unless much improved management can be attained.

Grazing capacity

A substantial increase in forage production results from clearing Guinea grass-wooded areas. Hopkinson (1969) reports that Guinea

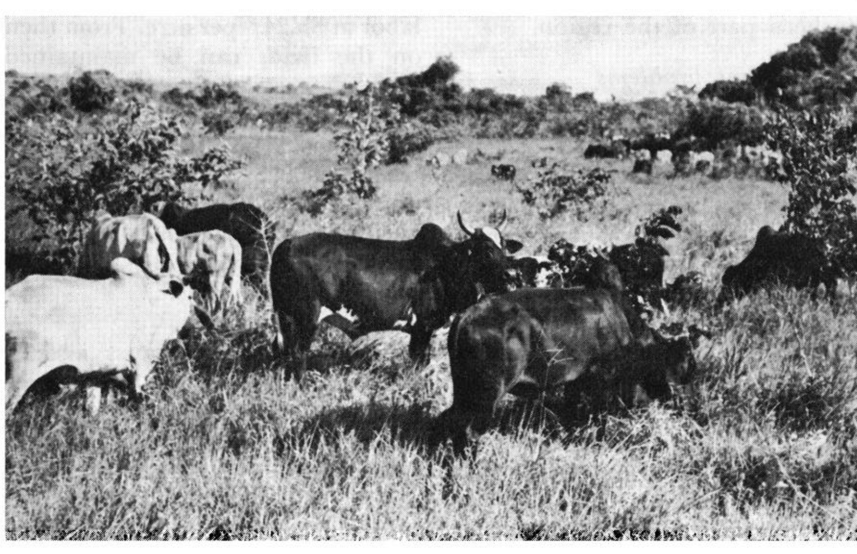


FIG. 4. Bush control must be considered a major concern.

grass can yield as much as 11,700 lb. per acre. The high forage production is the result of good soil fertility and better water holding structure of the soil. The cleared areas thus have a higher stocking rate than the coastal plain. At Magunga with good management it is possible to carry 1 animal unit yearlong on 6 acres and this is acceptable for the areas that once were cleared for sisal production. To bring the undeveloped wooded areas up to this carrying capacity, bush must be controlled.

One method of appraising the economics of bushcontrol is to consider the total cost of the initial and follow-up control work on a land unit over a period of years. Bentley (1963) assumes that if the investment is amortized over a 20-year period at an interest rate of four to five percent, the net return each year must equal about ten percent of the initial investment. Thus, at a stocking rate of 6 acres, the initial investment in bush control is approximately Sh.660/- per animal unit. Kidner (1965) in studying beef production from feeding trials using different breeds of cattle, indicates that indigenous Zebu cattle in good condition have a low average live-weight gain potential of about 0.75 lb. per day. In terms of shillings and cents, 6 acres will realize a return of Sh.164/- per year at present price levels of Sh.0.60/- per lb. Although these costs justify the initial outlay of capital investment, bush clearing will remain a restriction for livestock development as long as costs for operation and maintenance of mechanical equipment continue to rise without subsequent recoveries from beef production.

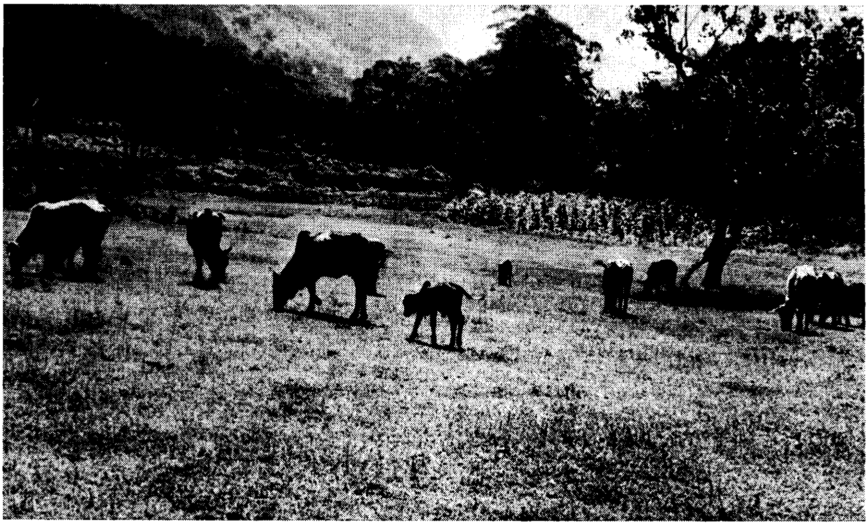


FIG. 5. The Usambara highland is suitable for intensive livestock management.

The Usambara Highland

The Usambara Highland has a cooler climate than the other range sites. Elevation ranges from 2000–6000 feet with a rainfall between 56 to more than 90 inches annually. The soils are a red loamy clay.

The Usambara Highland does not qualify as rangeland but is suitable for intense specialized livestock management (Fig. 5). At the higher elevations with cooler temperatures, steeper slopes, shallow soils, and an increased amount of rainfall, *Paspalum dilatatum*, *Melinis minutiflora*, *Pennisetum purpureum*, and *Pennisetum clandistinum*, a creeping rhizomatous sodforming grass, are the main forage plants. In the lower Usambaras *Panicum maximum*, *Cynodon dactylon*, *Digitaria scalarum*, and *Paspalum scrobiculatum* form the main perennial associations. In moist locations there are some robust growing species such as *Pennisetum trachyphyllum*, *Agrostis schimperiana*, and *Festuca gigantea*. The legumes *Glycine javanica*, *Clitoria ternatea*, *Vigna fragrans*, and *Dolichos taubertii* appear in good concentrations.

Management problems

The undulating topography of the hillsides accentuates a danger of soil erosion. The encroachment of cultivation on grazing lands with indiscriminate bush clearing for the cultivation of rowcrops is increasing the danger of soil losses unless conservation is practiced with terracing and maintaining a soil cover.

The Tanga Region Extension Service is teaching the farmers in the Usambara hills to plant Guatamala grass (*Tripsacum laxum*) for soil conservation with their tea plantings (Ministry of Agriculture, 1968). Where cultivation is not practiced the sodforming creeping grasses are desired for grazing. Since the erosion threat becomes pronounced with close grazing it is of vital importance that stocking rates are properly determined and management is practiced.

Grazing capacity

With the possibility of very productive seeded pastures and plantings of large fodder-type grasses and legumes, the grazing areas can become suitable for highly specialized livestock operations such as dairy farming or fattening of young stock. At Amani, Kikuyu grass (*Pennisetum clandistinum*) is providing excellent grazing and it has been reported earlier, (Eichinger, 1914) that in Amani seven head of milking cattle were kept on ten acres of *Paspalum dilatatum* pastures and with never a feed shortage.

The Masai Steppe

The Masai Steppe is a large area that covers most of central and northwest Tanzania. Lower rainfall, 18–25 inches, and vegetative characteristics bring the steppe into a different site category. It will not be discussed in this article for the Tanga region.

Conclusions

Sisal production is now being restricted and livestock keeping is becoming increasingly important. Most sisal growers feel reluctant to engage in such a new and different enterprise and more detailed information is needed that should form the basis for the planning and utilization of this vast grazing resource. With an estimate of the grazing capacity the viability of ranch operations on sisal lands and on native lands can be better evaluated for needed water developments, fencing, bush control, reseeding, and livestock programs. Four range sites were delineated in the Tanga Region of Tanzania. Their estimated capacities varied from 1 animal unit yearlong on 8 acres to 1 on less than 2 acres. Lower grazing capacities occur on the Masai Steppe, but is not covered in this article. Capital investments for improvements can be justified where the estimated grazing capacities can can be achieved or present conditions markedly increased with intensive management. When cattle keeping in these areas is recognized as an integral part of range management it can become a highly profitable enterprise. With a potential of 500 square miles of cleared sisal land beef production in the Tanga Region of Tanzania promises to be a successful and a very viable undertaking which is catering to an even growing market in East Africa.

Literature Cited

BENTLEY, J. R. 1963. Bush control in Kenya. Ministry Agric. Kenya U.S. AID, Nairobi, Kenya.

EICHINGER, A. 1914. Die Weide und Futterverhaltnisse von West Usambara Beiheft zum Pflanzen No. 2:5.

HOPKINSON, D. 1969. The potential of some pasture species in the sisal areas of the Tanga Region of Tanzania. (Unpublished manuscript) Mlingano Sisal Research Station, Tanga, Tanzania.

KIDNER, E. M. 1965. Beef production, Part 2. E. Afr. Agr. F.J. 32:91–95.

MINISTRY OF AGRICULTURE. 1968. Annual report. Tanga Region Extension Service. Dar es Salaam, Tanzania.

NAVEH, Z. 1966. The need for integrated range research in East Africa. Trop. Agr. Trin. 43:95–97.

OWEN, M. A. 1968. Studies with beef steers on the Kongwa plain, Central Tanzania. Trop. Agr. Trin. 45:159–171.

STEVENS, B. A. 1969. Livestock manager, Tanzania Sisal Corporation. (Personal communication.)

VAN RENSBURG, H. J. 1948. Notes on fodder and pasture plants in Tanganyika Territory. E. Afr. Agr. F. J. 13:149–152.

VAN RENSBURG, H. J. 1948. Notes on some browse plants. E. Afr. Agr. F. J. 13:164–166.

Changing Educational Needs for Research, Teaching, and Extension[1]

R. KEITH ARNOLD

Deputy Chief for Research, Forest Service, U.S. Department of Agriculture, Washington, D.C.

Highlight

To unlock the complicated interrelationships of the range, scientific and managerial talents of the highest order are needed. This paper suggests goals for range management education and proposes one strategy for achieving these goals in the universities. The appropriate faculty can provide strong training for range professionals and meet the general education needs of the university community and other professionals as well.

Range management, along with many other professions, is entering a new and exciting era. That era may well be characterized by the name "Quality of the Environment." The 1970's are already characterized as the "Environmental Decade," ushered in by President Nixon in his State of the Union message on January 22, 1970. There are three overriding precepts which set the stage for us in considering the new and exciting era:

1. There is the increasing public concern about man's global environment. Every turn of the radio or TV dial, nearly every printed page reveals that man's concern about his environment is really the question "Can man exist for long on earth?"
2. Of particular concern to us is the fact that the conservation movement is broadening from preoccupation with minerals, wildlife, and wilderness to an awareness of the whole balance of nature and the total environment of man.
3. Despite our awareness and concern and even some beginnings of action, our environment continues to deteriorate. Pollution, degradation, and destruction of natural ecosystems and natural beauty are proceeding faster than corrective counter-measures. Man's technology, his capacity for modifying the environment, has been and is increasing faster than his knowledge of its impacts on the environment.

The Forest Service is now sharpening its concepts, studying new approaches, and employing new techniques to look at the problems of management and protection of our rangelands. And the key to satisfactory solutions to these problems is analysis of the total ecosystem—including trade-offs between environmental concerns and productivity concerns.

---

[1] Presented at the annual meeting of the American Society of Range Management, Denver, Colorado, February 1970. Accepted for publication March 28, 1970.

As we approach our job of studying, managing, and protecting the range, we find the analysis of ecosystems involves many familiar and traditional features. We have long recognized the multiple values of range resources and the complexity of their interacting factors. There are, however, facets of the job that are new or now have greater importance.

In the past, we studied and worked with the rangelands with a central emphasis on maximizing livestock production. Our treatments never strayed too far from the optimum for livestock production. We're still going to work with livestock. But rather than isolating grazing as a part of the total ecosystem, we'll extend the boundaries of our research to find what interdependencies are important. We're going to measure the responses to grazing management in terms of livestock production. But we're also going to measure those responses in terms of other goods and services—water, timber, fish, wildlife, etc. In essence, we'll study the entire complex system.

How or why, you might wonder, did we come to adopt this approach? Research has brought us here in part. We have learned to think increasingly of cause-and-effect phenomena, not in terms of two simple variables but, in systems. Computers and technology of sufficient sophistication to handle problems of our complex ecosystems have become available.

I would like to pause here to relate the complexity of our problems of managing range ecosystem with the complexity of the problems which placed a man on the moon. Computers were able to monitor completely all the plans, all the crises, and all the alternative actions, and to have solutions ready to use in a micro-second's time. I doubt if the computer exists that could store such information about plans, operations, and alternatives for the world's ecosystems. It can certainly handle major parts of it, but not the entire problem. And, of course, not the entire solution. Furthermore, basic understanding of the long- and short-range changes going on in the soil, plant, air interaction—the effects of pollution; possible effects of weather modification; effects of intensive management over time—just isn't available.

To unlock the complicated interrelationships of the range—including plants, animals, environment, and people—we need scientific and managerial talent of the highest order. The demands on and opportunities for educational programs are unprecedented.

At the outset, I emphasize that we do not expect our scientists and managers to become systems analysts. Although the techniques of systems analysis are implicit in our approach to research, we would prefer to hire analysts to render support services to our scientists.

The analysis of our major ecosystems will require an interdisciplinary team of expert researchers having a variety of knowledge and skills. The team is needed because of the complexity of our systems and the unique manner in which different disciplines view the same ecosystem. Members of this research team must have a thorough and modern knowledge of one or more of the basic sciences, broad working knowledge of each other's field, and an awareness of the capabilities of the powerful economic and statistical tools that are available. And I hasten to add—the proper balance of the liberal arts and humanities.

The undergraduate education of a range manager must continue to be flexible. The baccalaureate may be followed by graduate study for careers in science or education or immediate employment in resource management or livestock production on privately owned ranches. The individual student chooses among these alternative careers in the latter part of or often after his undergraduate education. And he may switch to another alternative after a few years of employment.

Regardless of his choice of careers, the range manager must be given a broader education. He cannot practice his chosen profession adequately unless he understands the relationship of the range to the total environment and the interrelated, often conflicting, desires of the range users. His background should include survey courses in wildlife, watershed, forest, and recreation management. Or existing range courses may be modified to include these uses—emphasizing the unity of the range resource rather than the diversity of range uses. To increase this interdisciplinary orientation of students, traditional organization lines within the universities must give way.

Greater breadth of education should not be achieved at the expense of liberal arts and the basic sciences. These, too, need strengthening. But, we should reexamine range curricula that still require such courses as poultry and dairy husbandry, horticulture, and field crops. Such courses are too distantly related to the native ranges and their multiple products.

Greater emphasis must be placed on principles and concepts of the basic sciences and less on the technology of range management. If well versed in the basic sciences, the student can readily assimilate and use the technology of range management. He can grow with new technology and ensure his professional stature.

Let's stop right here! I am falling into the trap of outsiders trying to tell the professional educators how to do the very thing the educators alone know best. May we back off now, and identify some goals for range management education, list some of the problems which universities face in achieving these goals, and suggest one strategy for achieving them.

Until recently, I was directly involved in developing educational programs at the University of Michigan for the rapidly changing fields of natural resources management.

I have also had the opportunity to be a member of the FAO International Committee on Forestry Education and to serve as consultant to a number of universities on Natural Resources Programs. Consequently, I appreciate the magnitude of this task and more critically, the question, "Is there a place for Range Management in today's and tomorrow's university?"

I would like to suggest four goals for range management education, and I would hasten to add that these goals are not unique to the field of range management. They certainly apply to other natural resource areas and probably to every professional field taught in universities. First, a university education should provide a sense of relevance—in our case the relevance of range management to man's continued existence on this earth.

By sense of relevance, we also create a sense of the importance of range management to mankind, and its importance for the production of beef and for the creation and maintenance of a quality environment.

The second goal is a sense of urgency. Range management is, has always been, a long-time proposition. We have had time to take five, ten, even twenty years to work out new grazing systems, new forms of management. But in this decade of environmental quality, if we do not produce in universities those who can consult and advise on policy and those who can relate range management to the rest of man's activities, the range manager will become a high level technician under those who have either achieved the broader role or who have assumed it by default.

The third goal is that of interdisciplinary communication. Range managers must interact, day by day, with all other resource managers. This communication has been traditional. But today's world also requires communications among natural scientists, social scientists, and engineers. If such communications and interactions do not start in the universities, they will never be satisfactory for the real world problems.

The fourth and last goal I would like to identify is the capacity and motivation to learn. In the past, those of us in education have been more concerned with what should be in the curriculum rather than with creating the ability to continue to learn after graduation. It is physically and mentally impossible to provide course work which covers everything that a range manager should know. The argument about a 4-year curriculum versus a 5-year curriculum is spurious—neither one is sufficient. In effect, we suggest a life-long curriculum in which a man learns how to learn in a university and has enough professional background in his chosen discipline to allow him to earn his pay on the first job he gets. This goal not only suggests an increasing capability and motivation to learn on the part of the individual, it also requires continuing educational programs in the universities.

It is important that we recognize the problems which universities face as they create the institution, the organization, the educational system if you will, to achieve these goals. There are certain characteristics intrinsic to the university as an institution which must be recognized. For example, there are weak incentives for interdisciplinary teaching as well as interdisciplinary research. Recognition in terms of promotion and salary is largely based on publication in professional journals and on creative graduate instruction leading to successful Ph.D's. The discipline-oriented department or professionally oriented department is the traditional university structure provided for the group of discipline or professionally oriented educators. Departments are not structured for interdisciplinary communication. Social scientists and engineers are rarely made at home or even made to feel at home in a natural resource department. These departments have no peer group at hand to evaluate their professional and teaching progress. The student has a broader challenge than the faculty! This entire problem area is complicated further by the vigor with which freedom of research interest is regarded by the academic community—and rightly so. It is only recently that universities have sensed the nature of this problem and are working to create new institutions to meet it head on.

In terms of range management, I believe part of the answer lies in a wide variety of curricula and of organization in universities to meet the need for range managers.

I don't propose to know the answer or even to know the one best approach. I would like to suggest one strategy which may be profitable for several universities to follow. This strategy also eliminates the question which every university president faces—can he afford a given program or professional school or professional department. In this day of rising costs, universities are looking with a critical eye at the costs involved in small professional curricula. In terms of range management, the question often is, Can this university really use some of its scarce resources to teach professional range management? I suggest we turn the question around to read like this—Can a university—or can this university really afford not to have the educational and research resources required to educate outstanding professionals in the field of range management?

The tactics required go something like this: For a university to meet the general educational requirements and specialized professional requirements in all fields critically concerned with the quality of the environment, there must be available on the campus professors with knowledge of systems ecology, soils, hydrology, resource economics, and other disciplines directly contributing to range management. Since cellular biologists have largely captured the teaching and research in botany and zoology in universities, the natural resource field now provides the best home for those rather basic scientists concerned with the growth, development, and maintenance of animals, plants, and man in ecosystems. The professional staff of the range-environment unit provides service courses on the natural environment to the general university community. Other highly specialized courses are given for other professions such as law, engineering, public health, and medicine.

If this faculty is selected with care, it can meet the needs I have described for the general education of the university community and other professions. It will also have that combination of individual professional strengths which provides the strongest possible professional training in the light of the four goals already identified. Some of you may feel that this suggestion deemphasizes the profession of range management. I would argue, on the contrary, that this kind of an educational strategy will guarantee not only the continuation of professional range management education, but it will allow it to develop and enlarge its position of leadership so critically needed in over one-half of the area of the United States.

Larger Pits Aid Reseeding of Semidesert Rangeland[1]

ROBERT D. SLAYBACK AND DWIGHT R. CABLE

Manager, Plant Materials Center, Soil Conservation Service, USDA, Tucson, Arizona; and Range Scientist, Rocky Mountain Forest and Range Experiment Station,[2] Tucson.

Highlight

Broad, shallow intermediate pits have proved to be longer lasting than conventional pits on semidesert range in the 6- to 8-inch summer rainfall zone in southern Arizona. Rainfall penetration averaged twice as deep in the pits as on adjacent flats. Herbage production of buffelgrass averaged 2½ times as high, over a 4-year period, on the intermediate pits as on conventional pits, and five times as much as on similar adjacent untreated range.

Buffelgrass (*Cenchrus ciliaris*), in 1967, produced over five times as much herbage on a semidesert area pitted with a recently developed intermediate pit as on an adjacent area with conventional pits, and nearly nine times as much as similar untreated range. These results were obtained in a cooperative study by the Soil Conservation Service Plant Materials Center, University of Arizona, and the Forest Service on the Santa Rita Experimental Range, about 25 miles south of Tucson, Arizona.

Although conventional pits have often given good initial establishment of seeded grasses, they usually lose much of their effectiveness in retaining and storing water after the first year or two. Their reduced effectiveness is due largely to rapid filling of the pits with soil following typical torrential summer storms, and to excessive competition from native annual grasses and forbs. To overcome these problems, a modified bulldozer blade was developed jointly by the University of Arizona and Soil Conservation Service (Frost and Hamilton, 1964) to construct broad, shallow pits that serve the dual purposes of scraping away the annual grass and forb seeds and of providing long-lasting basins (Fig. 1). These pits have been designated "intermediate" pits. The pits are so arranged that all surface runoff water must go into or through the pits.

In this study, the conventional method of pitting was compared to the intermediate pits to evaluate their relative effectiveness in establishing buffelgrass, an introduced perennial grass from India that appears to be well adapted to this part of the southwestern semidesert. The conventional method of pitting has previously been reported as pitting or interrupted contour furrows (Anderson, et al., 1957; Anderson and Swanson, 1949). This report summarizes buffelgrass yields from 1964 to 1967 on areas planted in 1963, 1964, and 1965, and moisture penetration measured in 1963.

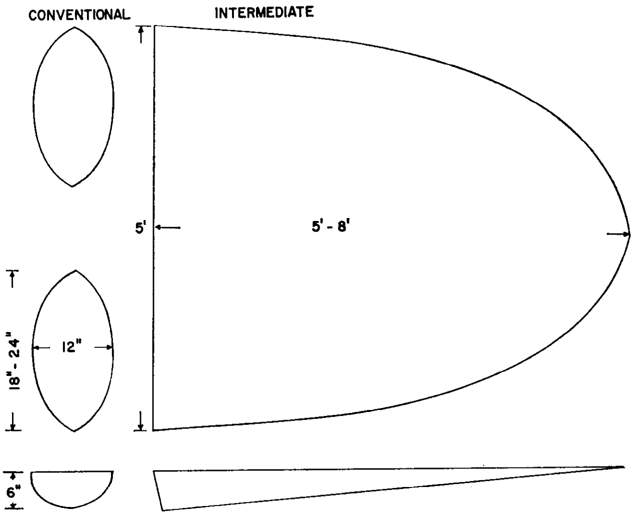


FIG. 1. Comparison of dimensions of conventional and intermediate pits.

[1] Received August 20, 1969; accepted for publication October 21, 1969.

[2] Central headquarters maintained in cooperation with Colorado State University at Fort Collins. Author stationed at Tucson, Arizona, in cooperation with the University of Arizona.

Area and Methods

The first of these annual plantings was made in May 1963 on the Santa Rita. The 29-acre study area is at about 3,000 feet elevation in Major Land Resource Area 40 (central Arizona basin range, Morris, 1965). The soils in the study area include slowly permeable clay loams, highly erosive sandy loams, and intermediate soils (Tubac, Sonoita, and Anthony series); replicate plots were installed on each of three soil types. The native vegetation included mainly velvet mesquite (*Prosopis juliflora* var. *velutina*), cholla cactus (*Opuntia* spp.), burroweed (*Aplopappus tenuisectus*), catclaw (*Acacia greggii*), six-weeks grama (*Bouteloua barbata*), and needle grama (*B. aristidoides*).

Prior to planting, the mesquite was killed with diesel oil and the area fenced to exclude livestock. Jackrabbits and other rodents used the area heavily, however. Harvester ants were controlled prior to each planting. In each of the 3 years 1963, 1964, and 1965, two plots 400 to 600 ft long and 2 or 3 pit-rows wide were established on the contour on each of the 3 soil types. One plot of each pair was pitted with a standard pitting disc and the other with the basining machine. The plots were then seeded to buffelgrass at about 1 lb/acre with a cultipacker seeder (1963 plantings were drilled as a part of the basining operation). The buffelgrass seed was purchased commercially and appeared to be the T-4464 strain of Texas origin. The intermediate pits were 6 inches deep at the lowest point (downhill side), 5 to 8 ft long, and about 5 ft wide. The conventional pits were about 18 inches long, 12 inches wide, and 6 inches deep.

One square 9.6 ft^2 quadrat was clipped in each of 10 pits in each plot annually in November after the season's growth was finished to sample production in the pits (systematic sample). Summer rainfall was measured on the site with a recording rain gage. Moisture penetration was measured with a soil probe every 7 to 10 days during the first summer, 1963.

Results and Discussion

Summer rainfall (July through September) for the 3 planting years varied widely (Table 1). The long-time average for the summer in this area is about 6.70 inches. Thus, 1963 was about 18% above; 1964, 69% above; and 1965, 22% below the long-time average.

Table 1. July, August, and September rainfall (inches) at Santa Rita Field Evaluation Planting.

Month	1963	1964	1965	1966	1967
July	4.06	5.95	1.60	2.43	3.53
August	1.94	1.95	1.55	3.18	2.34
September	1.94	3.45	2.08	1.06	.86
Total	7.94	11.35	5.23	6.67	6.73

Initial establishment of buffelgrass was strongly affected by the amount of rainfall in the year of planting, and this effect usually carried over to the following year. Thus, in 1964, the wet year, initial establishment was particularly good and the plots planted that year produced unusually well (194 to 990 lb/acre, Table 2). In 1965, the dry year, initial establishment was poor, and production on plots planted that year was too low to warrant measuring (even in 1966, five of the six plots planted in 1965 produced less than 100 lb/acre). However, this restriction in production, due to low rainfall in the year of planting, was only temporary; by 1967, the 1965 plantings were producing about as much buffelgrass as were the areas planted in 1963 and 1964 (except on the clay loam soil). Data for 1965 emphasize the importance of pits, and particularly of the intermediate pits, because production on the plots planted in 1963 and 1964 was about as high in 1965 as in 1966 and 1967, even though 1965 was a dry year.

The data in Table 2 also show that, for the 1963 and 1964 plantings, initial establishment of buffelgrass was better in the conventional pits than in the intermediate pits. However, production on the conventionally pitted plots generally declined after the second year because of decreasing capacity of the pits to hold water. The intermediate pits re-

Table 2. Summary of yields (lb/acre) of buffelgrass in conventional and intermediate pits at the Santa Rita Evaluation Planting.

Soil type	Year planted	1964 Conv. pits	1964 Int. pits	1965 Conv. pits	1965 Int. pits	1966 Conv. pits	1966 Int. pits	1967 Conv. pits	1967 Int. pits	Average Conv. pits	Average Int. pits
Sandy loam	1963	238	105	933	1100	1540	1063	880	1590	898	965
	1964	294	253	34	475	30	593	483	2310	210	908
	1965					22	244	36	1590	29	917
Loam	1963	0	612	143	870	5	503	93	568	60	638
	1964	410	194	193	693	31	146	80	483	179	379
	1965					37	83	103	1704	70	894
Eroded clay loam	1963	198	168	154	257	52	198	102	264	102	222
	1964	990	274	1230	1830	206	700	199	2102	656	1227
	1965					50	31	99	94	75	63

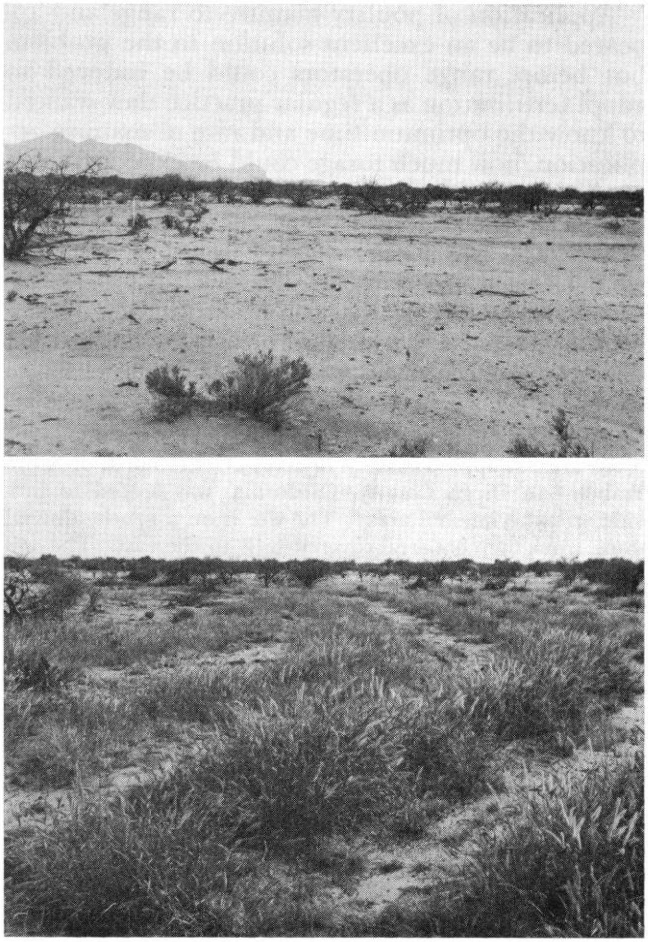


FIG. 2. Upper—Tubac clay loam severely eroded area before pitting. March 1964. Lower—Same area in 1967, showing buffelgrass in intermediate pits.

mained effective (Fig. 2) and were still effective, although partially filled, as of July 1969. The pits on the eroded clay loam have filled more than those on the loam and sandy loam soils.

Herbage production in 1967 averaged 1,189 lb/acre for all soils and dates of planting on intermediate pits but only 230 lb/acre on conventional pits. These differences were highly significant, but differences between soil and years of planting were not significant. Average production for the 4-year period was 2½ times as great on intermediate pits (690 lb/acre) as on conventional pits (253 lb/acre). The 4-year average production of native perennial grasses on adjacent mesquite-free range was 138 lb/acre. Mesquite-infested native range produced only 21 lb/acre. Production figures for pitting assume complete coverage of the treated area (no space between rows of pits).

Moisture penetration in the basins and on the flats between basins differed significantly among soils, between the two locations, and among sampling dates (Table 3). Penetration in the basins averaged 28 inches on the sandy loam soil, 22 inches on the loam, and 14 inches on the clay loam; penetration averaged only half as deep on the flats as in the basins for each soil type.

Table 3. Rainfall (inches) and moisture penetration (inches) in and adjacent to intermediate pits on the Santa Rita Experimental Range, 1963.

		Period ending					
		7/16	7/27	8/1	8/8	8/16	8/25
Rain during period		1.50	.90	2.00	.68	.25	.67
Moisture penetration:							
Sandy loam	– Flat[1]	5	9	22	10	17	22
	– Basin	24	26	34	27	28	28
Loam	– Flat	7	9	11	7	17	15
	– Basin	15	15	27	27	27	23
Clay loam	– Flat	2	8	15	5	5	6
	– Basin	11	12	19	16	15	12

[1] Penetration measured 2 to 3 ft from pits.

Conclusions

These results indicate that constructing intermediate pits on semidesert ranges results in deep percolation of rainfall, and in more successful, longer-lasting, and more productive stands of buffelgrass than can be obtained with conventional pits.

The results presented here constitute a progress report. Observations to determine the effective life of intermediate pits will continue. Additional trials are also under way with a modification of the intermediate pit to see if establishment and subsequent production of buffelgrass and other adapted forage species can be further improved. The economics of pitting and seeding have yet to be worked out, although increases in production attained to date make the procedure appear promising.

Literature Cited

ANDERSON, D., L. P. HAMILTON, H. G. REYNOLDS, AND R. R. HUMPHREY. 1957. Reseeding desert grassland ranges in southern Arizona. Univ. of Arizona Agr. Exp. Sta. Bull. 249:15–17.

ANDERSON, D., AND A. R. SWANSON. 1949. Machinery for seedbed preparation and seeding on southwestern ranges. J. Range Manage. 2:64–66.

AUSTIN, MORRIS E. 1965. Land resource regions and major land resource areas of the United States. U.S. Dep. of Agr. Handbook 296. 82 p.

FROST, K. R., AND L. P. HAMILTON. 1964. Mechanization of range reseeding. Prog. Agr. in Arizona 16(1):4–6.

Fertilization of Annual Rangeland with Chicken Manure[1]

CYRUS M. McKELL,[2] VICTOR W. BROWN, ROBERT H. ADOLPH, AND CAMERON DUNCAN

Professor of Agronomy, University of California, Riverside, California; Director, and Farm Advisor, University of California Agricultural Extension Service, San Diego County; and Laboratory Technician, Agronomy Department, University of California, Riverside.

Highlight

Changing patterns of land use caused by urban expansion may bring poultry operators into foothill areas and thus provide a cheap source of plant nutrients for rangeland fertilization. Research results with chicken manure applied to annual range indicate that application may be made in any season, with forage responses lasting into the third year after application. Forage quality and palatability are increased but the initial abundance of legumes is decreased by increased rates of chicken manure. Additional first year feed obtained from fertilization can be obtained for a cost of between $1.56 and $2.18 per AUM.

Fertilization of annual rangeland in California has been shown to be both biologically necessary and economically profitable. Various reports have outlined the need for fertilizer elements such as nitrogen, phosphorus and sulfur, the amounts required, season and methods of application, and the plant species which give the best responses. The work of Martin and Berry (1955, 1956) provides a practical guide for rangeland fertilization on a pasture basis.

A large factor in deciding whether commercial fertilizers should be used on rangelands to increase forage production has been the cost of the fertilizer. However, changes in markets, land use, and production levels have made large volumes of animal manures available to many rangeland operators. For example, a considerable portion of the estimated 80,000 tons (about 200,000 yards) of poultry manure produced annually in San Diego County, California was purchased by vegetable crop growers along the coast. Recent subdivision of the vegetable croplands, movement of the poultry industry into the foothills along with expanding urbanization and health department regulations which require frequent pen clean-out but prohibit stockpiling the manure forced the poultry industry to look for new avenues of manure disposal.

Application of poultry manure to rangeland appeared to be an excellent solution to the problem but before range operators could be induced to adopt fertilization as a regular practice they wanted to know the optimum time and rate of manure application, how much forage could be expected from fertilization with manure as contrasted with commercial fertilizer, how long the fertilizer effect would last, how forage quality would be affected, what effect the manure would have on forage legumes, and would fertilization be profitable. Therefore, a series of experimental plots were established to answer such questions.

Methods

An area of approximately 10 acres 2 miles north of Santa Ysabel, San Diego County, California, was fenced to provide an experimental area.[3] The site is on a gentle alluvial slope from the chaparral-covered hills to the east. The soil is classified as a clay loam. Preliminary soil tests indicated a deficiency in nitrogen, a deficiency in phosphorus, and adequate potassium. Annual precipitation is approximately 10 to 20 inches and occurs generally from October to May in a pattern typical of a Mediterranean climate.

Resident forage species include filaree (*Erodium botrys*), ripgut (*Bromus rigidus*), red brome (*Bromus rubens*), soft chess (*Bromus mollis*), annual fescue (*Festuca megalura*), native annual legumes, and broad leaf forbs. Prior to laying out the plots the entire area was drill-seeded with bur clover (*Medicago hispida*), rose clover (*Trifolium hirtum*), soft chess, hardinggrass (*Phalaris tuberosa* var. *stenoptera*), and smilo (*Oryzopsis miliaceae*) at rates of 2, 2, 5, 1, and 1 pounds per acre, respectively.

Seven treatments were replicated four times: (1) no fertilization, (2) 1 ton chicken manure per acre, (3) 2 tons chicken manure per acre, (4) 4 tons chicken manure per acre, (5) 70 lb. N plus 40 lb. P per acre, (6) 140 lb. N plus 80 lb. P per acre, and (7) 280 lb. N plus 160 lb. P per acre. Nitrogen was applied as ammonium nitrate and P was applied as trebble superphosphate in amounts calculated to be approximately equal to their concentration in the volumes of poultry manure used. A plot size of 30 ft $\times$ 30 ft allowed sufficient size for subsequent reapplication of fertilizer to one-half of the plot.

To evaluate the seasonal effect of the fertilizer on forage response and on the efficiency of the fertilizer, a new set of the seven treatments was applied fall, winter, and spring for four growing seasons. Winter-fertilized plots were treated each year before late winter temperatures began to increase. The spring-fertilized plots were treated after forage maturity so that the manure would be subject to summer temperatures and not available to plants until the subsequent growing season.

In October 1965 all fall-treated plots were split and refertilized to provide an interval of reapplication of 1, 2, and 3 years.

Forage production was estimated from 3 ft $\times$ 27 ft strips harvested from each plot at the full bloom state of rose

[1] Part of this research was financed by a grant-in-aid from the Poultry Industry Committee, San Diego Farm Bureau, San Diego, California. Received June 30, 1969; accepted for publication October 16, 1969.

[2] Present address, Head, Department of Range Science, Utah State University.

[3] Grateful acknowledgement is given to Mr. Victor Cauza for the use of the land for this study. The cooperation of poultry men in the area is also acknowledged for the supplies of chicken manure they provided for the study.

Table 1. First-year forage yields in pounds per acre of annual rangelands fertilized with chicken manure vs. comparable rates of inorganic fertilizer.

Fertilizer treatment	Date of fertilization, date harvested						Mean yield in excess of check
	Oct. 1962 May 1963	Mar. 1963 May 1963	June 1963 May 1964	Oct. 1963 May 1964	Jan. 1964 May 1964	June 1964 May 1965	
Check	650_a[1]	700_e	2710_h	3100_l	2450_q	3020_u	—
Chicken manure							
1 ton	1880_b	1240_{ef}	4260_i	5030_m	3490_r	5260_{vw}	1422
2 tons	2690_{bcd}	2260_g	5680_{ij}	5610_{mn}	4260_r	5710_{vw}	2263
4 tons	2900_{cd}	2690_g	7420_k	6780_o	6580_{st}	7460_w	3533
Inorganic							
$N_{70}P_{40}$	2310_{bc}	1560_f	3550_i	6000_{no}	5190_{rs}	4200_{uv}	1697
$N_{140}P_{80}$	2850_{cd}	2690_g	7030_{jk}	7870_p	6840_{st}	6270_{vw}	3487
$N_{280}P_{160}$	3550_d	2580_g	7870_k	7610_p	8070_t	7520_w	4095

[1] Values followed by the same letters do not differ significantly (5% level).

clover. *Bromus rigidus* was generally in the soft dough state at this time. A subsample of herbage was collected for moisture determination, separation into species components, and chemical analysis. Each fall soil samples from the top 6 inches were obtained for chemical analysis[4] and samples of the chicken manure remaining on the soil surface were returned to the laboratory for chemical analysis.

After the plots were sampled, cows were turned into the experimental area and allowed free-choice grazing of the dry feed. In 1963 a visual rating of the degree of utilization was made. Animal droppings were removed before the initiation of each new growing season.

Data obtained in the study were statistically analyzed according to a randomized block design. The Duncan Multiple Range Test was applied for mean separation within seasonal blocks.

Results

Fertilization with either chicken manure or inorganic fertilizer significantly increased first-year forage yields at the study site (Table 1). In all but one season of application (March 1963) the average response to 1 ton of chicken manure per acre (or $N_{70}P_{40}$) was significantly greater than the average yield for the check plots. On the average, 1 ton of chicken manure resulted in a first-year forage yield increase of 1420 lb., 2 tons of chicken manure increased yields by 2260 lb., and 4 tons of chicken manure resulted in forage yields of 3530 lb. per acre more than the check plots.

Yield increases resulting from either type of fertilizer were statistically equal at all rates studied with only two exceptions such as with the October 1963 application (Table 1). Even though there appeared to be a slightly higher yield from plots fertilized with inorganic fertilizer than with the chicken manure such differences were not statistically significant.

[4] Dr. Jack Rible, Extension Soils Technologist, University of California, provided the chemical analyses of the soil samples.

Variation in forage yield during the 5-year study was large (Fig. 1). Yields as low as 670 lb. of forage per acre were obtained from check plots in 1963 in a year of 18.5 inches precipitation. In 1967 the precipitation was over 21 inches and yields of 3590 lb. of forage per acre were harvested from the check plots. This latter figure is approximately equal to the average yield resulting from fertilization with 1 ton of chicken manure during the 5-year study.

Timing of fertilization throughout the year does not appear to be of critical importance. The additional forage produced over that of the check plots for the first 2 years after fertilization was approximately equal in the fall, winter, or spring. There appears to be a greater advantage for the application of chicken manure in the fall than in the spring and summer. Concern that there would be a loss of ammonia N from fertilizer left lying in the sun during the summer does not appear to be justified. Because of the shorter period available for

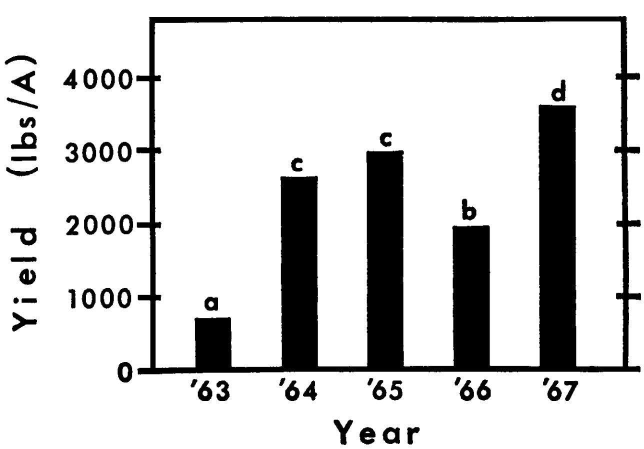


FIG. 1. Average annual variation of annual-range forage production as indicated by yields of check plots during a 5-year period (Santa Ysabel, California). Bars labelled with the same letter are not significantly different at 5%.

Table 2. Forage yields (lb./acre) for the first, second, and third years after fertilization. Data are averaged over time of season of application.

Treatments	First year[1]	Second year[2]	Third year[3]	Total yield in excess of check
Check	2304	2513	3030	
Chicken manure				
1 ton	3732	2825	3579	2289
2 tons	4462	3000	3649	3264
4 tons	5577	3045	4144	5859
Inorganic				
$N_{70}P_{40}$	3997	2413	2854	1417
$N_{140}P_{80}$	5264	2757	3510	3184
$N_{280}P_{160}$	5636	4308	3848	5940

[1] Each value is an average of 36 plots.
[2] Each value is an average of 28 plots.
[3] Each value is an average of 16 plots.

Table 3. Crude protein and phosphorus content (%) of annual range forage from fertilizer test plots harvested at maturity. (Fertilized fall 1963)*

Treatment	Crude Protein	Phosphorus
Check	6.6	.33
Chicken manure		
1 ton	7.0	.34
2 tons	7.7	.39
4 tons	8.9	.43
Inorganic		
$N_{70}P_{40}$	7.1	.38
$N_{140}P_{80}$	9.7	.45
$N_{280}P_{160}$	12.6	.54

* Figures are the mean of four observations.

the beneficial effect of the fertilizer it appears that winter fertilization with chicken manure is slightly less beneficial than fall application. This does not appear to be the case when inorganic fertilizer is used.

Cumulative forage yields for the first 3 years after fertilizer application indicate a beneficial carry-over effect from fertilization into the third season (Table 2). Yields from applications of chicken manure and inorganic fertilizer appeared to be equal for 3 years regardless of year to year variations. First-year yields were generally higher with the inorganic fertilizer, but the yields from chicken manure application appeared to hold up better in the second and third year and thus the cumulative totals for both types of fertilizer were about equal by the end of the third season. The low rate of chicken manure was more effective than the low rate of inorganic fertilizer during the second and third growing seasons.

On the basis of cumulative yields in excess of forage production from check plots for a 3-year period after fertilization it appears that each 50 lb. of N plus 21 lb. of P stimulated an additional 1000 lb. of forage yield.

Reapplication of fertilizer appears necessary after the third season to continue a high level of forage production. Fourth-year yields from the plots started in fall 1962 were generally no greater than check plots. No visual response to the fertilizer was discernible in the fourth year on plots fertilized early in the experiment.

Forage yields on nonreplicated plots, which received rates of chicken manure as high as 8 and 10 tons per acre, were only slightly higher than yields from the 4-ton rates. Plots were difficult to harvest and were usually later than the check plots to mature. No "burning" of the forage plants was noted although the physical presence of the large amount of chicken manure had a retarding effect on plant growth when applied in the winter or early spring.

Chemical composition of forage was altered by fertilization. Crude protein and P were both increased in the harvested forage (Table 3). Without any fertilizer applied the average protein content was 6.6%. At the highest rate of chicken manure fertilization the crude protein percentage was 8.9% as compared with 12.6% for inorganic fertilizer. The P content of forage was also increased proportionately. With no fertilization the forage contained .33% P, and on plots fertilized at a rate of 4 tons of chicken manure the P content was .43%. Forage from plots receiving the highest rate of commercial fertilizer contained .54% P.

Palatability increase is a commonly observed result of range fertilization, and in this study there appeared to be a relationship between the degree of animal use and the level of fertilization (Fig. 2). When the first year forage was grazed, cows preferred the commercial-fertilized forage over the chicken manure fertilized forage. Fertilized forage at all rates was preferred over the unfertilized forage.

In the years following fertilization there was a large increase in legume percentage all over the experimental area—including the check plots (Table 4). Legume response to fertilization was inversely proportional to the amount of N applied. Of the seeded legumes, Rose clover was the dominant species. Other legumes such as lupine (*Lupinus* spp.) and bur clover also increased in abundance during the years after fertilization. Legumes made up about ⅓ of the forage on the fertilized plots by the end of the fifth year after seeding and fertilization. In contrast, legumes made up almost ½ of the forage on the check plots after 5 years.

Nitrate values in the harvested forage were well below the range of toxicity to livestock. Even when

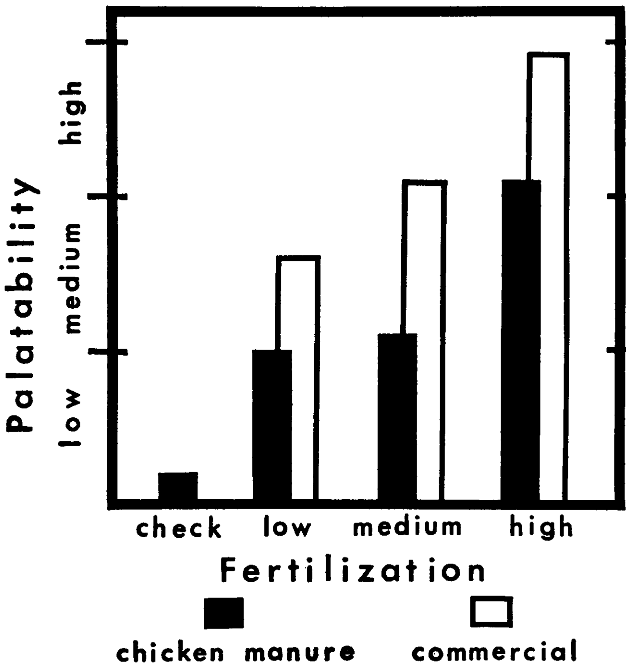


FIG. 2. Palatability of non-fertilized, commercial fertilized, and chicken manure fertilized annual range as determined from the degree of utilization.

plants were fertilized at high rates of chicken manure during the growing season nitrate values were not in the dangerous range. High application rates of inorganic fertilizer produced values as high as .12% NO_3-N but were still within the safe level for nitrate (Kendrick et al., 1955).

The breakdown rate of the chicken manure in the field was relatively slow but sufficient to stimulate plant growth equal in magnitude to the inorganic fertilizer. After 3–4 months in the field the N content of the surface-applied chicken manure decreased about 42% (Table 5). Further N decreases were much slower. Several months after application a considerable amount of chicken manure was still evident on the surface of the plots. Phosphorus changes in the chicken manure were

Table 4. Legume abundance (% by weight) in hand-separated samples from the first block of fertilized plots (1964 to 1967).

Treatments	1964	1965	1966	1967
Check	1	14	19	49
Chicken manure				
1 ton	1	19	23	41
2 tons	1	16	29	31
4 tons	1	17	9	24
Inorganic				
$N_{70}P_{40}$	0	26	40	26
$N_{140}P_{80}$	1	13	31	36
$N_{280}P_{160}$	0	12	31	21

Table 5. Fertilizer value (N,P) of chicken manure when applied in the field and 3 months later.

Date of application	Original fertilizer value (%)		Fertilizer value after 3 months (%)	
	N	P	N	P
November 1962	4.28	2.35	1.84	2.19
March 1963	4.59	2.28	3.31	3.18
June 1963	4.22	3.43	2.62	3.47
October 1963	5.40	2.89	2.88	3.00
Mean	4.62	2.74	2.66	2.96

considerably slower than N and appeared to be associated with a physical breakdown of the manure rather than with liberation by leaching.

The level of available P in the soil approximately doubled as a result of fertilizer application (Table 6). At the beginning of the study the P content of the soil of the site was about 5 ppm. One year after fertilization with the 4-ton rate of chicken manure the average P content was 13.1 ppm. Two years later the P level was 13.9 ppm and after 3 years 24.4 ppm. The value after 4 years was 15.1.

Discussion and Conclusions

Fertilization of annual rangelands with chicken manure appears to hold considerable promise as a range improvement practice in areas close to a source of supply. Inasmuch as poultry operators are obligated to frequently clean the manure from under the chicken cages and dispose of it, rather than stockpile it they are often willing to give it away to insure prompt removal. Thus, the cost to the range operator is for loading, hauling, and spreading. Results shown in these studies indicate that minor differences in forage yields from application at different times in the year are not significant. This allows the rangeland operator to spread

Table 6. Phosphorus increases (% P in fertilized plot—% P in check)[1] in soil samples from annual range as a result of fertilization. Plots fertilized October, 1962.

Treatment	Sampling Date: Nov. 1963	Nov. 1964	Dec. 1965	Aug. 1966	Mean
Chicken manure					
1 ton	4.4	3.2	5.0	2.3	3.7_a[2]
2 tons	7.1	8.4	8.6	4.6	7.2_{ab}
4 tons	8.1	9.0	14.1	10.0	10.3_b
Inorganic					
$N_{70}P_{40}$	4.6	7.5	4.9	3.7	5.2_a
$N_{140}P_{80}$	10.0	7.2	7.4	5.9	7.6_{ab}
$N_{280}P_{160}$	23.9	20.1	12.0	14.3	17.6_c
[1] Check	5.0	4.9	10.3	5.1	

[2] Values followed by same letters do not differ significantly (5% level).

poultry manure on his fields anytime during the year that weather and field conditions permit.

Weather variability from year to year is large in a mediterranean climate. Forage production varies considerably in response to favorable or unfavorable rainfall and temperature patterns. During the 5 years of this study forage production on check plots averaged from a low of 670 lb. per acre to a high of 3590 lb. per acre. Fertilization is more effective in producing additional forage in years of favorable weather than in years of unfavorable weather. However, the additional feed produced in a low rainfall year may be highly valuable to a rangeland operator because of feed scarcity. McKell et al. (1958) showed a 300% increase in the efficiency of precipitation for forage production on fertilized annual range. Martin and Berry[5] generally recommend rangeland fertilization with nitrogenous fertilizers in areas which receive an average of from 12–30 inches of precipitation.

As is the case with range fertilization in general, fertilization with chicken manure produces forage of a higher quality and palatability. Protein and phosphorus content were significantly higher in forage from fertilized plots. Other benefits of fertilization include a longer period of forage availability. Fertilized range is ready to use earlier in the season and, because of its higher palatability as dry feed, may be used with greater efficiency for grazing in the dry summer months.

The results from this study show that the fertilizer value of chicken manure is equal to equivalent rates of commercial fertilizer. There appears to be a slower release of fertilizer elements from the chicken manure than the inorganic fertilizer but over a 3-year period the net forage response was nearly equal.

Annual forage legumes do not appear to benefit initially from the application of chicken manure. The high rates of nitrogen cause a proportionately greater stimulation of grasses than the legumes. In subsequent years following fertilization when the high levels of N have been utilized by the grasses or lost by leaching the legumes appear to thrive on the increased level of available P and may be expected to make a substantial contribution to forage yield and quality.

In rural San Diego County operators of manure spreader trucks will spread poultry manure on land for $3.10 to $4.35 per ton, depending upon distances from poultry farm to areas using the manure.

A general average of 1600 lb. of extra feed was obtained for each ton of chicken manure. The value of this added feed may be expressed in animal unit months (AUM) or its equivalent (1 AUM = 800 lb. of hay for a 1000 lb. steer). Thus, the 1600 lb. of extra feed is equal to 2 AUM's and has a value of $5.00, using a local average of $2.50 per AUM. (Considerably higher values of an AUM are reported for other annual range areas). A net profit is, therefore, possible based on local prices of $3.10 to $4.35 per ton (2.5 yards per 1 ton) of poultry manure applied on the range.

[5] Proceedings of XI International Grassland Congress, 1970. (In press)

Literature Cited

KENDRICK, JOHN W., JOHN TUCKER, AND S. A. PEOPLES. 1955. Nitrate poisoning in cattle due to indigestion of variegated thistle (*Silybum marianum*). J. Amer. Vet. Med. Assoc. 126:53–56.

MARTIN, W. E., AND L. J. BERRY. 1955. Fertilized range can pay dividends. Second Progress Report. Results of ten grazing tests on annual range. 1954–1955 season. Univ. of Calif., Agr. Ext. Serv., 31 p.

MARTIN, W. E., AND L. J. BERRY. 1956. Range fertilization in a wet year. Third Progress Report. Results of 16 grazing tests on annual range. 1955–1956 season. Univ. of Calif., Agr. Ext. Serv., 49 p.

McKELL, C. M., J. MAJOR, AND E. R. PERRIER. 1959. Annual-range fertilization in relation to soil moisture depletion. J. Range Manage. 12:189–193.

Effects of Clipping and Supplemental Nitrogen and Water on Loamy Upland Bluestem Range[1]

CLENTON E. OWENSBY, ROBERT M. HYDE, AND KLING L. ANDERSON

Asst. Professor, Assoc. Professor, and Professor Emeritus respectively, Department of Agronomy, Kansas State University, Manhattan.

Highlight

Water and nitrogen were added separately and in combination to loamy upland bluestem range for four years. Plots were clipped at different dates. Moisture addition generally failed to increase total herbage yields, but supplemental nitrogen increased yields substantially. Nitrogen addition increased cool-season species in the stand. Moisture use was increased by nitrogen addition and reduced by clipping.

Moisture availability and nitrogen fertility have often been implicated as the principal environmental factors limiting herbage production in grasslands. In this study the relative importance of supplemental moisture and nitrogen for bluestem range, with attention to haying management, has been investigated.

Native prairie soils have a relatively fixed supply of nitrogen and a variable supply of rainfall (Jenny, 1930). Erratic herbage production due to variable precipitation may result in variable accumulation of nitrogen at different stages of the nitrogen cycle. For example, a series of years with above-normal precipitation could result in a tie-up of nitrogen in a nonavailable organic form, or, conversely, a series of years with below-normal precipitation could result in a build-up of available nitrogen in the soil. Thus, production might not be directly associated with precipitation in a given year, and nitrogen fertilization might then be based on previous years' precipitation.

Use of nitrogen fertilizer has increased the yield of herbage from True Prairie vegetation in the Kansas Flint Hills (Aldous, 1935; Huffine and Elder, 1960; Mader, 1956; Moser and Anderson, 1964). Herbage yield increases from nitrogen fertilization have approached economic feasibility, but changes in botanical composition to cool-season dominance have been a deterrent in application of this practice (Mader, 1956).

Nitrogen fertilizer also may be used to increase the protein content of native herbage (Aldous, 1935; Burzlaff et al., 1968; Gay and Dwyer, 1965; Mader, 1956; Moser and Anderson, 1965). Therefore, nitrogen fertilization of True Prairie grass herbage, which loses its crude protein content rapidly as it matures (Williams, 1953), results in higher quality forage.

In general moisture additions have been less effective in increasing herbage yields than have nitrogen additions (Klages and Ryerson, 1965; Smika et al., 1965). However, the combination of added nitrogen and added water has greatly increased herbage yields. Nitrogen addition also has increased moisture-use efficiency, perhaps in part because added nitrogen stimulates greater root exploration of the soil mass (McKell et al., 1962; Lorenz and Rogler, 1966).

Clipping, which removes transpiring tissue, reduces moisture use. Thus, Doss et al. (1966) in Texas reported that all species studied in their trials used more water prior to clipping than after clipping. A part of the reduction in moisture use, however, may be attributed to stoppage of root growth after clipping (Crider, 1955).

The work reported here evaluates the effects of added moisture and nitrogen on herbage yields, botanical composition, soil moisture, and herbage nitrogen percentage of bluestem range.

Materials and Methods

The study was conducted on a True Prairie loamy upland range described as ordinary upland by Anderson and Fly (1955) near Manhattan, Kansas. Since it was fenced in 1926 the plot site had been undisturbed and mulch accumulation was high. On April 25, 1965, standing vegetation was clipped to a 3-inch stubble and removed. Precipitation for the area is shown in Figure 1.

The experimental design was a split-split plot replicated four times. Main plots were years, subplots were three clipping treatments, and sub-subplots were four nitrogen and moisture additions. The circular plots had diameters of 4.5 feet. In late April, 1965, bands of 16-gauge aluminum 6 inches wide were buried in the soil to a depth of 4 inches around these plots so that water could be added. All plots were banded, whether they received water or not.

Main plot treatments.

The experiment was conducted during 4 consecutive years, 1965 through 1968. Treatments remained the same on each plot throughout the experiment.

Subplot treatments.

Clipped once. Herbage was clipped to a 3-inch stubble on October 1 of each year.

Clipped twice. Herbage was clipped to a 3-inch stubble on July 15 and October 1.

Clipped thrice. Herbage was clipped to a 3-inch stubble on July 15, August 15, and October 1.

Sub-subplot treatments.

Nitrogen. Nitrogen as ammonium nitrate was broadcast at the rate of 50 lb/acre on July 1 yearly.

Moisture. Water was added at irregular intervals (Table 1) sufficiently often in all mois-

[1] Contribution No. 1113. Department of Agronomy, Kansas Agricultural Experiment Station, Kansas State University, Manhattan. Received September 27, 1969; accepted for publication February 5, 1970.

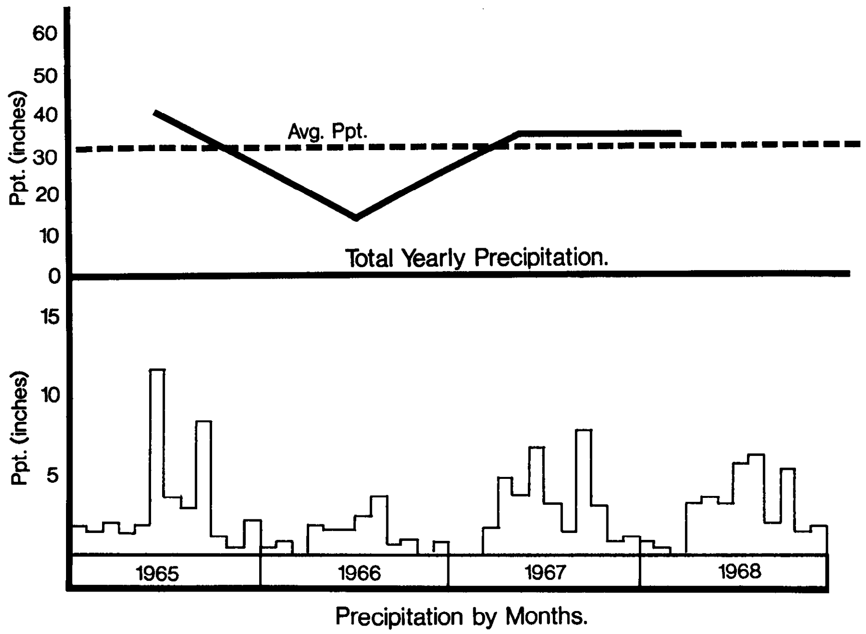


FIG. 1. Total precipitation by months and years from 1965 through 1968 at the Kansas State University Agronomy Farm, Manhattan.

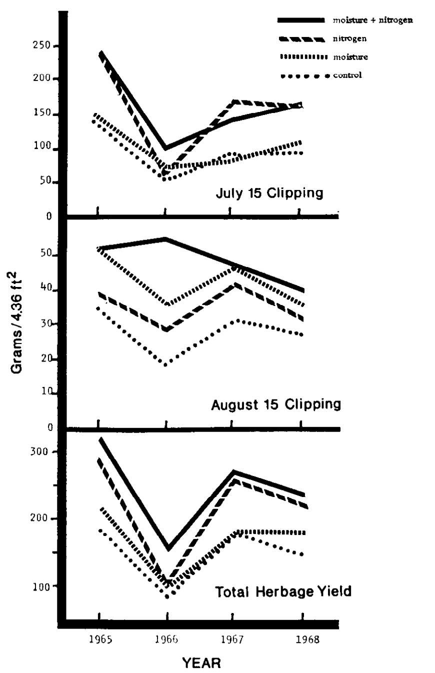


FIG. 2. Herbage yield (gm/4.36 ft^2, oven-dry) on July 15 and August 15, 1965–68, and total herbage yield (includes Oct. 1 clipping) from plots with different moisture and nitrogen treatments.

ture plots to maintain adequate soil moisture during the entire 4-year period.

Moisture + nitrogen. Water and nitrogen were added as indicated in moisture and nitrogen treatments above.

Control. Neither moisture nor nitrogen was added.

Sample areas (4.36 ft^2) from each plot were clipped to 3-inch stubble on dates previously indicated. Big bluestem (*Andropogon gerardi* Vitman) samples were taken at that time for Kjeldahl nitrogen determination (Hiller et al., 1948). Herbage was oven-dried and yields reported on a dry-matter basis in grams per sample plot.

Table 1. Herbage yields (gm/4.36 ft^2, oven-dry) October 1 from clipped-twice and clipped-thrice plots with different moisture and nitrogen treatments.

	Clipping treatment	
Treatment	Twice	Thrice
Nitrogen	65	32
Moisture	78	39
Moisture-plus-nitrogen	88	38
Control	67	33
$LSD_{.05}$	9	4

Botanical composition was determined by locating four 2 × 5 dm sample plots within each experimental plot. Plant stems originating at the soil surface were counted during mid to late June each year. Each stem was measured to the nearest square centimeter.

A neutron moisture probe, described by Van Bavel (1963), was used to take soil moisture readings as total soil moisture in all plots for each foot of a 5-foot soil profile. Sampling was twice monthly from April 1 to November 1 and once monthly during the remainder of the year.

Moisture-use efficiency was calculated as pounds of dry matter produced per inch of moisture incident on a given plot, based on precipitation from October 1 of the previous year to October 1 of the growing season. On plots with additional water that amount was added to the normal precipitation.

Results and Discussion

Herbage Yields

Herbage yields (Fig. 2) were higher during the first year of the experiment, 1965, than in other years. Even though natural precipitation was higher than normal in 1965, apparently some additional herbage increase was related to mulch removal prior to the beginning of the growing season. The following year, 1966, was extremely dry and yields on all plots were lower than in 1965. The addition of 18.5 inches of water to moisture plots failed to increase herbage yields unless additional nitrogen also was supplied. Another environmental factor must have been limiting in 1966; perhaps the higher than normal temperatures during July and August of that year prevented herbage yields from reaching those of 1965.

Contrary to expectations, moisture additions alone were generally not effective in increasing herbage yields. In 1965 herbage yields were increased on moisture-added plots above those of control plots, but in 1966 and 1967 no increases were obtained. Soil nitrogen carryover on control plots after dry 1966, indicated by higher percent nitrogen in

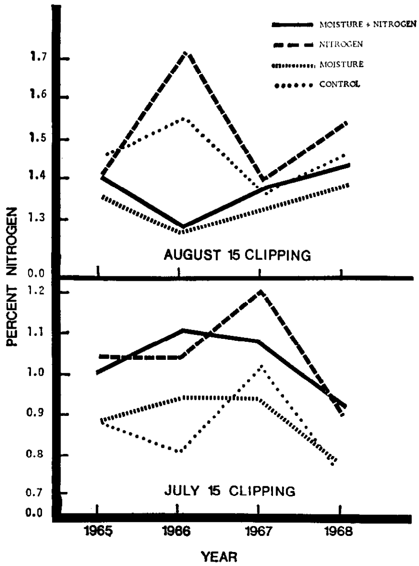


FIG. 3. Nitrogen (%) in big bluestem forage on July 15 and August 15, 1965–68, from plots with different moisture and nitrogen treatments.

the forage for control plots in 1967 than in other years (Fig. 3), probably stimulated growth on control plots. No nitrogen carryover occurred on moisture plots, since moisture additions eliminated drought effects; therefore less nitrogen was available on moisture plots than on control plots in 1967. In 1968 the increase in herbage production on moisture-added plots in relation to the control plots, together with similar nitrogen levels in the plants on moisture and control plots, indicates that in normal years moisture additions would increase herbage production, but not as much as would be produced by additional nitrogen.

Additional moisture appeared to be more effective in increasing herbage yields during the latter part of the summer, evidenced by increased herbage yields on moisture plots above that of control plots and on moisture + nitrogen plots above that of nitrogen plots at the August 15 and October 1 clipping dates (Table 1).

Nitrogen addition generally increased herbage yields on plots with and without added water. Only in dry 1966 were yields on nitrogen plots less than were those of the control plots. Nitrogen addition increased moisture-use efficiency (Table 2), agreeing with the results of Lehman et al. (1968) in work with irrigated blue grama (*Bouteloua gracilis* Lag. ex Steud.).

Table 2. Moisture-use efficiency (lb. dry matter/inch water) for different nitrogen and moisture treatments during 1965–68.

Treatment	Years 1965	1966	1967	1968
Nitrogen	157	130	183	163
Moisture	108	61	102	100
Moisture-plus-nitrogen	151	97	151	131
Control	101	115	183	112

Failure of moisture + nitrogen plots to produce much greater herbage yields than nitrogen plots in years with normal or above normal precipitation indicated that the nitrogen fertilization rate may not have been adequate on plots with supplemental water. Moisture-use efficiency, which was lower on moisture + nitrogen plots, substanciated that.

Plots clipped during July and August resulted in increased herbage production above that of plots clipped only at the close of the growing season. The 4 years of the study showed no reduction in herbage yield by following the July 15 hay cutting with an August clipping. Pressure exerted by clipping may not have been sufficient to influence herbage yields in the 4 years of the study. Cumulative effects over a longer period might have resulted in reductions in herbage yield due to the mid-August clipping following hay cutting on July 15.

Clipping during the growing season conserved moisture and increased moisture-use efficiency. Late season regrowth was increased by moisture additions and may have been partly responsible for higher moisture-use efficiency on plots clipped during the growing season.

Percent Nitrogen

Big bluestem herbage clipped on July 15 in 1965 and in 1968 showed higher nitrogen percentages on plots receiving additional nitrogen than on plots receiving only moisture or the control (Fig. 3). In 1966 percent nitrogen in big bluestem herbage on July 15 dropped below levels of 1965 in control plots. Moisture and nitrogen addition increased percent nitrogen in big bluestem plants on July 15 of that dry year (1966).

Reduced growth in 1966 apparently left soil-nitrogen levels higher than normal the following year on plots which did not receive additional water. Richardson (1935) inferred that in dry summers less of the readily available nitrogen in the soil was actually mobilized and used by plants. On July 15, 1967, the percent of nitrogen in big bluestem on control plots was higher than that in big bluestem on moisture plots, and the percent of nitrogen in big bluestem on nitrogen plots was higher than that in big bluestem on moisture + nitrogen plots. By 1968 the apparent imbalance had been negated and a pattern similar to the initial year was restored.

Mid-August nitrogen levels in 1965 in big bluestem regrowth on plots clipped July 15 indicated no difference in percent nitrogen due to moisture and nitrogen treatment (Fig. 3). In 1966, big bluestem regrowth from control and nitrogen plots had a much higher percent of nitrogen than that from moisture or moisture + nitrogen plots. That may have been due to a dilution effect, since regrowth herbage was higher on plots with additional moisture in 1966. Moisture and nitrogen treatments had little effect on the percent of nitrogen in big bluestem regrowth clipped in mid-August in 1967 and 1968.

At the close of each growing season moisture and nitrogen treatments had no effect on nitrogen levels in big bluestem. Big bluestem nitrogen levels on October 1 in 1966 were much higher than in other years, largely because of the higher nitrogen levels in big bluestem regrowth from plots clipped during the growing season.

Plots clipped twice during the growing season had higher nitrogen levels in big bluestem regrowth than had plots clipped once or not at all during the growing season. Apparently regrowth on plots clipped in mid-July had reached a stage of maturity at which nitrogen levels were similar to those on plots not clipped during the growing season.

Soil Moisture

Soil-moisture levels of nitrogen plots were generally lower than levels of control plots. Differences became greater as the growing season progressed, until mid-August when treatment effect lessened. In periods of limited precipitation moisture + nitrogen plots were usually lower in soil moisture than were moisture plots.

During periods of moisture stress, moisture levels were progressively lowered in the soil profile. That type of response was pointed out by Anderson (1965) in work with soil-moisture levels on burned plots and by Doss et al. (1962) in work with warm-season perennial forage species. Work by Dahlman (1968) in True Prairie supported that since water and nutrients in the lower portion of the soil profile would not be used until roots from the upper portion of the profile had grown into that area. Thus, those plants have no ability to use water in the lower portion of the soil profile until late in the growing season.

Clipping during the growing season reduced soil-moisture loss. Plots clipped in July had higher soil moisture late in the growing season than had plots not clipped during the growing season. Plots clipped in July and August had higher soil moisture in early fall than had plots clipped in July and October and in October alone.

Effects on soil moisture of different clipping and moisture and nitrogen treatments were erased in most years by precipitation during the dormant period for the warm-season species. Only in 1967, following dry 1966, did treatment effects carry over, and they were confined to the lower portion of the soil profile. The fact that treatment effects were obliterated following seasons with normal precipitation indicated no cumulative effects on soil-moisture levels due to treatment over years.

Plant Census

Basal cover of decreasers—i.e., big bluestem, little bluestem (*Andropogon scoparius* Michx.), and Indiangrass (*Sorghastrum nutans* (L.) Nash)—varied widely from year to year during the study. Basal cover of most species increased during the first three years of the experiment. That may have been because mulch buildup was removed at the beginning of the 1965 growing season. Weaver and Rowland (1952) reported thinned stands resulting from heavy mulch buildup in True Prairie. They found that big bluestem made up 80% of the basal cover of the area and that little bluestem had essentially disappeared. Their work agreed with results of this experiment, in which little bluestem made up relatively little of the stand. Further increase in basal cover may have been due to nutrient carryover into 1967 from dry 1966. Basal cover of most species dropped in 1968. Percent composition of decreaser species during

Table 3. Basal cover ($cm^2/0.4m^2$) and total basal cover (%) of decreaser species for different moisture and nitrogen treatments averaged over three clipping treatments.

	Treatment				
	$LSD_{.05}$	Nitrogen	Moisture	Moisture + nitrogen	Control
			Basal cover		
Decreasers	32	223	257	255	241
Big bluestem	19	131	141	158	121
Indiangrass	14	68	92	86	76
			Total basal cover		
Decreasers	3.6	58.3	69.5	64.8	64.3
Big bluestem	4.8	35.5	39.5	41.2	34.3
Indiangrass	3.2	16.8	23.9	20.6	20.1

Table 4. Basal cover ($cm^2/0.4m^2$) and total basal cover (%) for increaser species on plots with different moisture and nitrogen treatments.

	$LSD_{.05}$	Nitrogen	Moisture	Moisture + nitrogen	Control
			Basal cover		
Increasers	15	91	50	72	69
Tall dropseed	4	13	6	9	8
Kentucky bluegrass	16	53	23	40	30
Sideoats gramma	10	16	9	12	23
			Total basal cover		
Increasers	3.1	21.1	13.4	17.1	17.0
Tall dropseed	1.0	3.3	1.6	2.2	2.1
Kentucky bluegrass	2.2	11.4	5.9	9.1	7.4
Sideoats grama	1.6	3.9	2.2	2.9	5.1

Table 5. Basal cover ($cm^2/0.4m^2$) of Kentucky bluegrass during 1965–68 on plots with different moisture and nitrogen treatments.

	Treatment			
Year	Nitrogen	Moisture	Moisture + nitrogen	Control
1965	11	8	11	8
1966	32	27	29	37
1967	88	23	48	31
1968	82	34	72	42
	$LSD_{.05}$ = 36[1] = 33[2]			

[1] LSD for differences due to nitrogen and moisture treatment within a year.
[2] LSD for year differences within a nitrogen and moisture treatment.

the 4 years of the study remained relatively stable.

Moisture addition stimulated increased basal cover of decreaser species on moisture and moisture + nitrogen plots above that of nitrogen plots but did not differ in basal cover of decreaser species from the control (Table 3). Percentage of total basal cover of decreaser species was lower on nitrogen plots than on the control plots, reflecting an increase in basal cover of increaser species (Table 4). Clipping treatments did not differentially affect basal cover or percent composition of decreaser species.

Nitrogen addition resulted in increased basal cover of increaser species, i.e., Kentucky bluegrass (*Poa pratensis* L.), tall dropseed (*Sporobolus asper* (Michx.) Kunth), and sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.). The principal increase came from Kentucky bluegrass (Table 4). Apparently addition of moisture on plots with added nitrogen slowed increases in Kentucky bluegrass basal cover (Table 5). That indicated nitrogen stimulated early-season growth of Kentucky bluegrass and subsequent early season use of soil moisture, which had the effect of lessening the competitive ability of the warm-season grass species. When moisture was added, that effect was lessened.

Clipping treatment did not affect increaser basal cover. Percentage of total basal cover of increasers followed the same trends as basal cover response in relation to treatments.

Perennial-forb basal cover was not affected by moisture and nitrogen treatment, but it increased on clipped thrice plots (Table 6). That may have been in response to increased pressure on the warm-season grasses clipped in mid-August. Many of the perennial forbs in this study had completed their life cycle before that clipping date and were probably unharmed by the clipping treatment. Percent composition of perennial forbs varied in much the same manner as did basal cover of that group.

Sedges (*Carex* L. spp.) increased in basal cover on plots with additional nitrogen. Most of the sedges encountered on those plots were cool-season species and would thus benefit from early-season additional nitrogen much the same as Kentucky bluegrass.

Conclusions

Increased dry-matter yields of 0.75 to 1.0 tons/acre on nitrogen plots above that of control plots in years of normal or above normal precipitation were shown. Moisture addition resulted in smaller yield increases. Increased yields of herbage from nitrogen fertilization were shown in years of normal or above-normal precipitation without the addition of water. Nitrogen fertilization also increased crude protein of the forage, and moisture-use efficiency was highest on nitrogen plots. Higher moisture use on nitrogen plots was not reflected in successive seasons.

The primary negative aspect of nitrogen fertilization was the insidious shift in composition toward cool-season species, which was probably aided by apparent nitrogen carryover from dry 1966. The slower shift toward Kentucky bluegrass in moisture + nitrogen plots resulted from more nitrogen use on those plots than on nitrogen plots in 1966 due to supplemental water. Greater nitrogen use resulted in less available nitrogen for cool-season species use in the following year on moisture + nitrogen plots.

Moisture-use efficiency and percent nitrogen in the forage indicated that nitrogen applied, and not used, in a dry year was not wasted. Some of that nitrogen apparently was recovered in the following season. Fertilization rates following a dry year probably should be lower than normal to take advantage of that recovery.

Shifts toward cool-season species tend to negate any favorable responses to nitrogen fertilization. Those shifts would result eventually in high percentages of Kentucky bluegrass, a species with low drought-tolerance and inherently lower productive capacity than the native warm-season species in True Prairie.

Use of nitrogen fertilization as a management tool in True Prairie must be held in abeyance until

Table 6. Basal cover ($cm^2/0.4m^2$) and total basal cover (%) of perennial forbs on plots with different clipping treatments.

	Clipping treatment			
	$LSD_{.05}$	Once	Twice	Thrice
Basal cover	10	25	20	35
Percent composition	2.1	7.0	4.7	7.9

some economic means is found to control the shift to cool-season species. That means may well be properly-timed range burning or herbicide application.

Literature Cited

ALDOUS, A. E. 1935. Management of Kansas permanent pastures. Kansas Agr. Exp. Sta. Bull. 272. 44 p.

ANDERSON, KLING L. 1965. Time of burning as it affects soil moisture in an ordinary upland bluestem prairie in the Flint Hills. J. Range Manage. 18:311–316.

ANDERSON, KLING L., AND C. L. FLY. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Manage. 8:163–169.

BURZLAFF, D. F., G. W. FICK, AND L. R. RITTENHOUSE. 1968. Effect of nitrogen fertilization on certain factors of a western Nebraska range ecosystem. J. Range. Manage. 21:21–23.

CRIDER, F. J. 1955. Root growth stoppage resulting from defoliation of grass. U.S. Dep. Agr. Tech. Bull. 1102. 22 p.

DAHLMAN, R. C. 1968. Root production and turnover of carbon in the root-soil matrix of a grassland ecosystem. U.S.S.R. Acad. Sci. Int. Symp. on Methods of Productivity Studies in Root Systems and Rhizosphere Organisms. Publishing House "Nauka," Leningrad Branch, U.S.S.R.

DOSS, B. D., D. A. ASHLEY, O. L. BENNETT, AND R. M. PATTERSON. 1966. Interactions of soil moisture, nitrogen, and clipping frequency on yield and nitrogen content of coastal bermudagrass. Agron. J. 58:510–512.

GAY, C. W., AND D. D. DWYER. 1965. Effect of one year's nitrogen fertilization on native vegetation under clipping and burning. J. Range Manage. 18:273–276.

HILLER, A., J. PLAZIN, AND D. D. VAN SLYKE. 1948. A study of conditions for Kjeldahl determination of nitrogen in proteins. J. Biol. Chem. 176:1401–1420.

HUFFINE, W. W., AND W. C. ELDER. 1960. Effect of fertilization on native grass pastures in Oklahoma. J. Range Manage. 13:34–36.

JENNY, HANS. 1930. A study of the influence of climate upon the nitrogen and organic matter content of the soil. Missouri Agr. Exp. Sta. Res. Bull. 152. 66 p.

KLAGES, M. G., AND D. E. RYERSON. 1965. Effect of nitrogen and irrigation on yield and botanical composition of western Montana range. Agron. J. 57:78–81.

LEHMAN, O. R., J. R. BOND, AND H. V. ECK. 1968. Forage potential of irrigated blue grama with nitrogen fertilization. J. Range Manage. 21:71–73.

LORENZ, R. J., AND G. A. ROGLER. 1966. Root growth of northern plains grasses under various fertilizer and management treatments. Proc. Amer. Forage and Grassland Council. 1–11.

MADER, E. L. 1956. The influence of certain fertilizer treatments on the native vegetation of Kansas Prairie. Ph.D. Diss. Univ. of Nebr. 116 p.

MOSER, L. E., AND K. L. ANDERSON. 1964. Nitrogen and phosphorus fertilization of bluestem range. Trans. Kansas Acad. Sci. 67(4):613–616.

MCKELL, C. M., M. B. JONES, AND E. R. PERRIER. 1962. Root production and accumulation of root material on fertilized range. Agron. J. 59:459–461.

RICHARDSON, H. L. 1935. The nitrogen cycle in grassland soils. Trans. Third Int. Cong. of Soil Sci. 1:219–221.

SMIKA, D. E., H. J. HAAS, AND J. F. POWER. 1965. Effects of moisture and nitrogen fertilizer on growth and water use by native grass. Agron. J. 57:483–486.

VAN BAVEL, C. H. M. 1963. Neutron scattering measurement of soil moisture: development and current status. Proc. Int. Symp. on Humidity and Moisture. Washington, D.C., May 20–23, 1963.

WILLIAMS, JOHN S. 1953. Seasonal trends of minerals in prairie grasses. J. Range Manage. 6:100–108.

WEAVER, J. E., AND N. W. ROWLAND. 1952. Effects of excessive natural mulch on development, yield, and structure of native grassland. Bot. Gaz. 114:11–19.

BALLOTS AND DUES

Ballots and dues notices are mailed to all members of the Society on October 1 each year. This year the membership is asked to vote not only for a president elect and two new directors, but also on several proposed changes in ASRM's Articles of Incorporation. The candidates and the proposed changes are presented in the August and October issues of *Rangeman's News*: please read this material carefully, then return your ballots before November 30, 1970.

1971 dues are payable on or before January 1, 1971. Effective support of the Society can best be demonstrated by a prompt return of both ballots and dues payments.

Factors Influencing Intake of Mineral Supplements by Cattle on Southern Forest Range[1]

V. L. DUVALL AND L. B. WHITAKER

Assistant Director and Range Technician, Southern Forest Experiment Station, USDA, Forest Service, New Orleans and Alexandria, Louisiana.

Highlight

Among cattle fed cottonseed cake daily in winter, salt and bonemeal consumption was greater on moderately grazed range (48% utilization) than on ranges grazed either lightly (32%) or heavily (57%). Cattle on heavily grazed range ate much less bonemeal than others. On ranges grazed moderately, cattle fed cake on alternate days in winter consumed the most salt from *ad libitum* supply and also ate the most bonemeal. Cattle self-fed a cottonseed meal-salt mixture ranked second in bonemeal consumption and lowest in voluntary intake of salt. Total salt eaten annually by these animals was much greater than for those fed protein supplement by other methods, however, and voluntary intake continued yearlong, even though the ration furnished far more salt than needed in winter.

Resumen

El estudio se llevó a cabo en el estado de Louisiana en un pastizal de *Andropogon tener* y *Andropogon divergens*, comprendiendo como potreros pastoreados con vacas todo el año, con tres cargas de pastoreo, pesada, moderada y ligera. Los animales que disponian de harinolina diariamente durante el invierno, consumieron más sal y harina de hueso en la carga moderada (40% de uso de forraje producido) en relación a las otras dos. En la carga pesada consumieron menos harina de hueso. También las que consumieron harinolina en forma terciada (un día si y otro día no) pero en la carga moderada, consumieron más sal y harina de hueso que las otras dos cargas. Las vacas suplementadas con una mezcla de harinolina y sal ad libitum, ocuparon el segundo lugar en el consumo de harina de hueso y el último en el de sal, sin embargo, la cantidad total de sal consumida por dichos animales, fue el más alto.

For efficient production, breeding cattle grazing pine forest range in the South need salt and a high-phosphorus supplement yearlong (Duncan and Epps, 1958). Stockmen often provide salt and steamed bonemeal *ad libitum*, but cattle may not always ingest sufficient quantities. Evidence of phosphorus deficiency among cattle having access to bonemeal has been found (Black et al., 1949; Duvall and Hansard, 1967). Whether the cattle consume enough salt to satisfy their needs is problematic, since symptoms of mild deficiencies may escape detection.

This paper identifies factors associated with low intakes of salt and bonemeal furnished *ad libitum* to cowherds grazing forest range yearlong. Variables evaluated include season, grazing intensity, lactation, and method of feeding protein supplement.

Methods

The investigation was made in central Louisiana from October 1, 1965, through September 28, 1967. Five contiguous range units, varying from 480 to 590 acres, were studied. When the trial began, three supported stands of artificially regenerated slash pines (*Pinus elliottii*) from 2 to 5 years old. The remaining units were sparsely stocked with second-growth longleaf pines (*P. palustris*).

Herbage was similar on all ranges throughout the study. Slender bluestem (*Andropogon tener*) and pinehill bluestem (*A. divergens*) were the main grasses. Other important forage plants included panicums (*Panicum* spp.), paspalums (*Paspalum* spp.), and miscellaneous bluestems. Annual production averaged about 2,000 lb/acre (air-dry). Small hardwood trees—principally blackjack and post oaks (*Quercus marilandica* and *Q. stellata*), southern and dwarf waxmyrtles (*Myrica cerifera* and *M. pusilla*), and shining sumac (*Rhus copallina*)—were widely scattered in some units and fairly abundant in others.

All units were grazed yearlong. Cows were typical "native" stock, as described by Duvall and Hansard (1967). Bulls were either Angus or Shorthorn. Cows were bred for late fall and winter calving. Calves were marketed directly off the cows between August 10 and 15.

Beginning in mid-January, grass–legume hay was furnished at 3 to 4 lb/head daily. Since range forage is seriously deficient in protein from fall until spring (Duvall and Hansard, 1967), cows and bulls were supplied 417 lb each of cottonseed cake or meal (41% crude protein) from November 1 through May. Cottonseed cake or meal allowances averaged:

Period.	Amount (lb)/adult animal/day.
Nov. 1 to 30	1.0
Dec. 1 to 31	2.5
Jan. 1 to March 10	3.0
March 11 to 31	2.0
April 1 to May 31	1.0

Two sets of three treatments each involved combinations of grazing intensities and feeding methods. In Set I, three range units were stocked for different grazing intensities: light, moderate, and heavy. All cattle grazing these units were fed cake daily in winter. In Set II, three units were grazed moderately, but cattle were fed by different methods: cake fed daily, cake fed on alternate days, and salt-meal mixture self-fed. One combination, moderate grazing and daily feeding, was common to both sets; hence, treatments totaled five.

For the three grazing intensities in Set I, average utilization percentages were 32, 48, and 57. Herbage

[1] Received September 8, 1969; accepted for publication November 29, 1969.

Table 1. Percent of herbage utilization for cattle fed cottonseed cake daily in winter.

Grazing intensity	Year ending March		
	1966	1967	1968
Light	29	32	35
Moderate	44	52	47
Heavy	55	56	59

use, measured by the caged-quadrat method of Duvall and Whitaker (1963), is shown by unit and year in Table 1. In these units, cattle were fed on a schedule designated as daily because cake was distributed every day during the critical winter period, December 1 through March 31. In November, April, and May, they were fed on alternate days; a 2-day allowance was distributed at each feeding. Hay was provided daily from mid-January until new herbage was adequate.

In Set II, cattle grazing one unit were fed cake daily in winter as described for Set I. In another unit, the distribution schedule was designated as alternate-day, i.e., cake was supplied every other day from December 1 through March 10. A 2-day allowance was distributed at each feeding. During November and from March 11 through May 31, a 3-day allowance was distributed every third day. Hay was fed at the same frequency as cake. In the third unit, a mixture of one part salt to three parts meal (by weight), calculated to last for 2 or 3 days, was placed in bunks each year on November 1 (Duvall, 1969). After initial rate of consumption was determined, the mixture was adjusted until meal intake averaged about 1 lb/cow-day. Thereafter, the proportion of salt was changed as necessary to attain prescribed intake of meal; the supply was replenished every 5 days. Hay feeding for the salt-meal treatment was the same as for alternate day feeding.

In all five units, steamed bonemeal (10% phosphorus) and loose salt were provided yearlong in separate compartments of a covered feeder. These supplements, weighed after drying at 140 F until a constant weight was attained, were dispensed weekly. Each time, remainders were collected, dried, and weighed. Consumption was computed for 28-day periods by subtracting quantities recovered from those dispensed. By this method, intake by calves was indeterminable. Quantities consumed appeared relatively small, however, since calves were seldom observed at feeders before early summer.

Results

Salt Consumption

Among cattle fed daily, salt consumption averaged greatest for those on moderately grazed range (Table 2). Houston (1963) reported similar findings. Cattle on intermediately stocked range in Montana consumed more salt than those grazing at either heavier or lighter intensities; less available browse on the summer range stocked intermediately possibly accounted for that difference. In the present study, browse was most plentiful on the moderately grazed unit, but cattle ate little or none during summer.

Salt intake did not differ appreciably between lightly and heavily grazed units. It averaged 1.39 lb/animal/28-day period for heavy use and 1.42 lb for light.

Regardless of grazing intensity, cattle fed daily consumed the least salt during spring, when new herbage was most abundant. This finding generally agrees with those of Halls and Southwell (1954), Houston (1963), and Hughes and Southwell (1963).

Intake increased during summer but declined after calves were removed and lactation ceased in mid-August. This decrease was modest, suggesting that quantity eaten by the calves and the requirement for late lactation were not great.

Cattle on moderate and heavily grazed range consumed the most salt in fall. Cattle on lightly grazed range reached peak consumption considerably later; they ate more in winter than in fall.

On moderately grazed ranges, consumption was greatest for cattle fed on alternate days. Quantity taken annually from the free-choice supply was much less for cattle fed the salt-meal mixture than for those hand-fed cake. During the feeding season, cattle assigned to the salt-meal treatment consumed only 0.68 lb/head each 28 days, whereas cattle on other moderately grazed

Table 2. Average voluntary consumption (pounds) of salt per adult animal per 28-day period, 1965–66 and 1966–67.

28-day period ending	Grazing intensity and feeding method				
	Light-daily	Heavy-daily	Moderate-daily	Moderate-alternate-day	Moderate-salt-meal
10/28	1.15	1.60	3.19	2.63	2.66
11/25	1.68	1.40	2.77	3.18	1.77
12/23	1.83	1.38	1.56	3.18	0.68
1/20	1.86	1.50	1.38	2.66	0.24
2/17	1.64	1.38	1.50	2.04	0.36
3/17	1.64	1.18	1.20	1.71	0.72
4/14	1.14	1.08	0.78	1.23	0.30
5/12	0.88	0.98	1.06	1.55	0.57
6/9	1.49	1.15	1.89	1.87	1.92
7/7	1.13	1.43	2.40	2.08	2.36
8/4	1.56	1.73	2.53	2.07	2.80
9/1	1.18	1.60	1.96	1.94	1.74
9/29	1.25	1.61	2.03	1.92	1.90
Total	18.43	18.02	24.25	28.06	18.02
Average	1.42	1.39	1.87	2.16	1.39

Table 3. Average consumption (lb) of bonemeal per adult animal per 28-day period, 1965–66 and 1966–67.

28-day period ending	Grazing intensity and feeding method				
	Light-daily	Heavy-daily	Moderate-daily	Moderate-alternate-day	Moderate-salt-meal
10/28	0.84	1.42	2.02	3.56	3.37
11/25	1.65	1.00	1.42	3.32	3.76
12/23	0.92	0.87	0.80	2.24	1.97
1/20	1.48	0.74	0.70	2.74	1.06
2/17	0.78	0.76	0.44	1.85	0.88
3/17	1.04	0.54	0.94	1.50	1.27
4/14	0.76	0.54	0.41	0.62	0.44
5/12	0.24	0.27	0.72	1.00	0.54
6/9	1.40	0.54	2.08	2.01	1.97
7/7	1.24	0.92	2.80	3.36	3.46
8/4	1.60	1.49	3.13	4.64	3.74
9/1	1.46	1.36	1.95	3.61	2.36
9/29	0.87	0.98	1.80	2.84	2.84
Total	14.28	11.43	19.21	33.29	27.66
Average	1.10	0.88	1.48	2.56	2.13

ranges averaged 1.93 lb. Even so, voluntary intake by the self-fed herd was surprisingly high, because large quantities of salt were also ingested from the salt-meal mixture. During November through May intake from the latter source ranged from 8 to 34 lb/head/28 days and averaged 146 lb/head annually. When meal or cake was not furnished, the self-fed cattle voluntarily consumed about the same quantities as cattle on other moderately grazed ranges—1.99 and 2.08 lb/head/28 days.

For cattle fed on alternate days or supplied salt-meal mixture, as for those fed daily, voluntary intake was lowest in spring. Intake increased during summer and diminished after calves were weaned. Peak intake was in October for cattle fed daily, in November and December for those fed on alternate days, and in July for those fed the salt-meal.

Bonemeal Consumption

Among cattle fed daily, bonemeal consumption was greatest for those grazing moderately and least for those grazing heavily (Table 3). Thus, the rankings were the same as for salt intake. Annual intake on moderately grazed range averaged about 19 lb/adult animal. Duvall and Whitaker (1963) reported 29 lb for cattle fed daily on similar range that was 35% utilized. In that investigation, however, grass hay was fed and cottonseed cake allowance was only 373 lb. In the present study, the grass–legume hay and the 44-lb increase in cake provided additional phosphorus.

On moderately grazed ranges, cattle fed on alternate days ate the most bonemeal yearlong and those self-fed the salt-meal ranked second. The difference was greatest during the feeding season, when cattle fed on alternate days consumed 1.3 times as much as those that were self-fed. During the remainder of the year the alternate-day-fed herd averaged only 1.1 times as much.

Bonemeal consumption on moderately grazed range was least for the cattle fed daily. Most of the difference was accounted for during the feeding season, when intakes for alternate-day and salt-meal treatments were 2.6 and 1.9 times greater than for daily feeding. During the remainder of the year differences were much less.

For all treatments, bonemeal intake was generally least between mid-March and mid-May. Although phosphorus content of herbage is usually highest during this season, the main species are deficient for lactating cows (Duncan and Epps, 1958). Quantity ingested increased steadily from May until early August, when intake was at or near peak levels. Calves were weaned shortly afterward and consumption subsequently declined. By October or November, herbage had matured and phosphorus content was undoubtedly inadequate for dry cows; Campbell et al. (1954) found that the main bluestem grasses contained less than 0.07% at this stage. Bonemeal intake increased after herbage matured but declined after December 1, since the 2.5-lb daily allowance of cottonseed meal or cake furnished considerable phosphorus.

Lactation Effects on Mineral Intake

Lactating cows require more sodium, chlorine, and phosphorus than nonlactating cows (Morrison, 1943; NAS–NRC, 1963). Although reproductive rate, and therefore the proportion of lactating cows, varied considerably among both treat-

Table 4. Voluntary consumption (lb) of salt and bonemeal per 28-day period, by treatment, calving percentage, and year.

Grazing intensity and feeding method	Calving percentage		Salt intake		Bonemeal intake	
	1965–66	1966–67	1965–66	1966–67	1965–66	1966–67
Light-daily	69	76	1.31	1.53	0.92	1.28
Heavy-daily	58	68	1.38	1.39	0.94	0.82
Moderate-daily	63	75	1.83	1.90	1.45	1.50
Moderate-alternate-day	43	95	2.18	2.13	2.45	2.67
Moderate-salt-meal	45	63	1.34	1.43	1.86	2.40

ments and years, it apparently was not a major factor influencing intake of bonemeal or salt (Table 4).

Discussion and Conclusion

Under conditions of this trail, cattle on ranges stocked to utilize about 48% of current herbage ate more salt and bonemeal than cattle on ranges grazed at either heavier or lighter intensity. Bonemeal intake by the herd on heavily grazed range was especially low, averaging only 60% as much as for cattle grazing at moderate intensity. No reason for this difference was apparent. Cook et al. (1953) reported that as utilization by sheep on Utah range increased, phosphorus in residual forage diminished. It was expected, therefore, that cattle on Louisiana range would react similarly, increasing intake of bonemeal as grazing intensity increased. The drastic departure from the expectation could imply that intense grazing caused cattle to utilize plants low in palatability but high in phosphorus; however the supply of such forages was meager, especially from midsummer until spring.

Among cattle on moderately grazed ranges, bonemeal consumption and voluntary intake of salt were greatest for those fed cake on alternate days during winter. Duvall (1969) reported evidence that this method of protein supplementation stimulated grazing, and the eating of mineral supplements may have been similarly affected. As compared to daily feeding, the self-feeding of salt-meal mixture also apparently stimulated bonemeal consumption.

The self-fed cattle ranked lowest in voluntary intake of salt but highest in total quantity consumed. Although salt eaten with the meal greatly exceeded requirements, voluntary intake continued throughout the feeding season. The animals had obtained salt *ad libitum* before the study began and had apparently established a habit that persisted, despite the newly created source. Reynolds and Lindahl (1969) concluded that quantity of salt ingested *ad libitum* by sheep depended to some extent on the level to which they had become accustomed. For whatever reason, the yearlong intake from the free-choice supply in the present study discredits the widespread belief that cattle will voluntarily take only needed amounts of salt.

Literature Cited

Black, W. H., L. H. Tash, J. M. Jones, and R. J. Kleberg, Jr. 1949. Comparison of methods of supplying phosphorus to range cattle. U.S. Dep. Agr. Tech. Bull. 981, 22 p.

Campbell, R. S., E. A. Epps, Jr., C. C. Moreland, J. L. Farr, and F. Bonner. 1954. Nutritive values of native plants on forest range in central Louisiana. La. Agr. Exp. Sta. Bull. 488, 18 p.

Cook, C. W., L. A. Stoddart, and L. E. Harris. 1953. Effects of grazing intensity upon the nutritive value of range forage. J. Range Manage. 6: 51–54.

Duncan, D. A., and E. A. Epps, Jr. 1958. Minor mineral elements and other nutrients on forest ranges in central Louisiana. La. Agr. Exp. Sta. Bull. 516, 19 p.

Duvall, V. L. 1969. Comparison of supplementation methods for cow herds grazing pine-bluestem range. J. Range Manage. 22:182–187.

Duvall, V. L., and S. L. Hansard. 1967. Responses of southern range cattle to protein supplementation. J. Range Manage. 20:153–157.

Duvall, V. L., and L. B. Whitaker. 1963. Supplemental feeding increases beef production on bluestem-longleaf pine ranges. La. Agr. Exp. Sta. Bull. 564, 18 p.

Halls, L. K., and B. L. Southwell. 1954. Consumption of minerals by cattle on southeastern Coastal Plain forest range. J. Range Manage. 7: 163–165.

Houston, W. R. 1963. Salt consumption by breeding cows on native range in the northern Great Plains. J. Range Manage. 16:12–16.

Hughes, R. H., and B. L. Southwell. 1963. Mineral consumption related to improved cattle management systems in Georgia. J. Range Manage. 16:109–113.

Morrison, F. B. 1943. Feeds and feeding. 20th ed. The Morrison Publishing Co., Ithaca, N.Y. 1050 p.

National Academy of Sciences–National Research Council. 1963. Nutrient requirements of beef cattle. Publication 1137, 30 p.

Reynolds, P. J., and I. L. Lindahl. 1969. Effects of pelleting of forage on the *ad libitum* salt and water consumption and urine excretion of sheep. J. Anim. Sci. 28:563–567.

Lana Vetch for Medusahead Control[1]

ROBERT S. MAC LAUCHLAN, HAROLD W. MILLER, AND OSWALD K. HOGLUND

Plant Materials Specialist, Plant Materials Center, Soil Conservation Service, Pleasanton, California; Regional Plant Materials Specialist, Soil Conservation Service, Portland, Oregon; and Plant Materials Center Manager, retired, Pleasanton.

Highlight

Medusahead is invading California and western Oregon rangeland at an alarming rate. Overseeding with Lana vetch, a self-perpetuating annual legume, appears to be one of the most practical controls. Because Lana vetch can be successfully established without seedbed preparation it offers a practical method of controlling medusahead on rough terrain. Increased production and improved quality of forage from infested annual grass range are the result.

Lana vetch, an improved variety of woollypod vetch (*Vicia dasycarpa* Ten.) offers considerable promise for controlling one of California's and southwestern Oregon's worst range weeds—medusahead (*Taeniatherum asperum* (Sink.) Nevski) (formerly known as *Elymus caput-medusae* L) (Fig. 1).

Lana, a reliable self-seeding, winter-active annual legume was developed by the Soil Conservation Service and the University of California Agricultural Experiment Station. It is one of conservation's most versatile plants. Miller et al. (1964) reported on its use to improve forage quality and quantity and to extend the season of use of annual range forage in the Mediterranean-like climatic area of California and southwestern Oregon. He reported that forage production of resident annuals at Sunol, California was increased from an average of 1280 lb/acre to 3646 lb/acre when Lana vetch was added. Average annual production was increased to 5370 lb/acre when the Lana was fertilized annually with superphosphate at the rate of 400 lb/acre.

Medusahead is invading California and western Oregon rangeland at an alarming rate. As reported by Turner et al. (1963), medusahead occurs throughout an area of over 1,500,000 acres in southwestern Oregon. The periphery of known infestations in California is even greater. Major et al. (1960) reported that grazing capacity on some ranches had been reduced by as much as 75 percent by this grass.

The Pleasanton Plant Materials Center since 1960 has been retesting Lana vetch to determine its value for medusahead control. Results have been variable, depending on soils, fertilization, and grazing management. These tests show, however, that when Lana vetch is fertilized with phosphate and sulfur and grazing is deferred for late use the medusahead is suppressed. The results of one field trial are shown in Table 1.

For rangeland on which conventional equipment can be safely used for seedbed preparation and seeding, controlling medusahead is relatively easy. Work conducted by the Soil Conservation Service on Non-Pareil silt loam in southwestern Oregon showed that medusahead was completely controlled by: (1) starting mechanical seedbed preparation before the medusahead had set seed; (2) summer-fallowing; and (3) establishing, fertilizing, and properly managing any one of several adapted grasses and/or legumes, including Lana vetch.

Although tillage was beneficial in initial stand establishment, Luebs and Laag (1963) confirmed that Lana vetch could be successfully established without cultivation. Drilling was superior to broadcasting. Drilling Lana at 15 pounds per acre resulted in an average seedling emergence of 3.9 plants/ft^2, while only 1.4 plants/ft^2 were obtained from broadcasting. Other studies (Table 2) show that an initial stand averaging 1.5 plants/ft^2 developed into a maximum stand by the end of the third year. Maximum stands were consistently obtained by drilling 10 lb of Lana vetch seed per acre directly into undisturbed residue. For broadcasting seeding 20 lb/acre of Lana seed is recommended.

Lana vetch should always be inoculated. Kay (1967)[2] found that good inoculation can be consistently obtained by seeding lime pellet-inoculated seed.

Vast areas of medusahead-infested rangeland are too steep or stony to permit conventional seedbed preparation. On these areas, several methods of medusahead control, including burning, herbicides, soil sterilants, and overseeding plus fertilization, show promise. One of the most practical controls appears to be suppression of medusahead by overseeding with a self-perpetuating annual legume.

Several annual legumes, including subclover, have been evaluated. All but Lana require early season grazing to reduce the grass competition. Lana does best when completely deferred for late use. This deferment results in rapid growth and the formation of a dense canopy during the late spring, which competes seriously with the late-developing medusahead (Fig. 2).

Lana is adapted to a wide variety of soil and rainfall conditions. It performs well on coarse to fine-textured soils where rainfall is 16 inches or more.

[1] Received September 4, 1969; accepted for publication February 13, 1970.

[2] Letter from Mr. Burgess L. Kay, University of California, Davis.

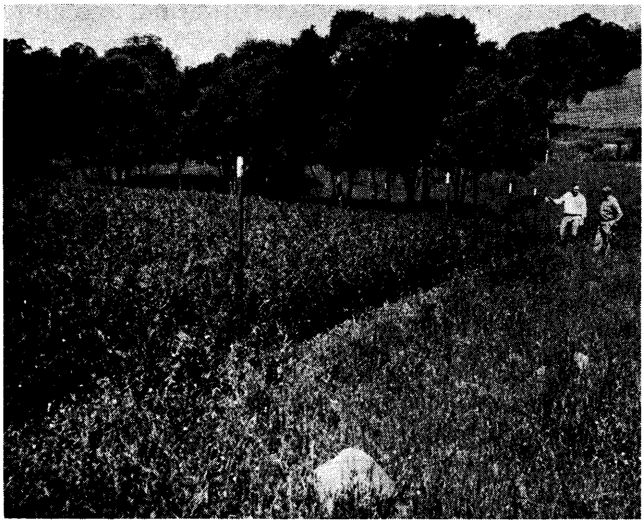


FIG. 1. This excellent stand of Lana vetch, in contrast to the ungrazed resident annuals outside the exclosure, demonstrates how the competitive growth and dense canopy of Lana can suppress late-developing medusahead.

It is adapted to soils ranging from moderately acid to moderately alkali. It is not suited to areas in which winter temperatures drop below 15 F.

Lana maintains its nutritive quality and high palatability after maturity when the quality of the resident annuals is at its lowest.

The crude protein percentage of Lana vetch samples collected in July from six field plantings in western Oregon are shown in Table 3. The percentage of crude protein varied from a low of 9.10 to a high of 14.73. The average was 11.54. This is several times the crude protein of the resident annual grasses at this time of the year, as reported by Gordon and Sampson (1939).

Mature Lana is relished by livestock and good gains have been reported (Fig. 3). A 45-acre Lana pasture plus a small amount of silage supplement produced 185 lb/acre of beef in 1964 on the Sam Noble ranch in Livermore, California. Mr. George Churchill, Yoncalla, Oregon, reported 181 cow days/acre of grazing of Lana vetch in 1965. He reported, based on actual weights, that calves gained 1.6 lb/day without supplements.

Table 1. Effects of superphosphate on Lana vetch seeded on a medusahead infested range on the John Black farm, Santa Rosa, harvested June 1966.[1]

	Dry forage (lb/acre)		
Treatment	Lana	Other[2]	Total
No treatment	0	4,160	4,160
200 lb/acre 0-20-0[3]	2,560	2,560	5,120
400 lb/acre 0-20-0	10,080	1,120	11,200

[1] Spreckles loam—Class VIe3.
[2] Medusahead and other annual grasses.
[3] Applied in the fall as single superphosphate.

Table 2. The average number (per ft^2) of Lana vetch plants obtained by drilling on undisturbed rangeland at Sunol as influenced by seeding rates (lb/acre).[1]

	Seeding rate[2]		
Counts	10	20	30
End of 1st year (4 plantings)	1.5	2.7	3.8
End of 2nd year (3 plantings)	4.5	5.7	6.7
End of 3rd year (2 plantings)	8.6	9.4	9.5
End of 4th year (1 planting)	11.9	11.7	11.5

[1] Positas gravelly clay loam Class VIe3.
[2] Seedings made fall of 1955, 1956, 1957, and 1958. Counts made spring of 1956, 1957, 1958, and 1959.

Many medusahead-infested soils are so infertile that annual fertilization with superphosphate is required to maintain an adequate percentage of Lana. Nitrogen bearing fertilizers defeat the purpose, resulting in vigorous grass growth which suppresses the Lana vetch. Table 4 shows the effects of superphosphate, treble phosphate, and ammonium–phosphate–sulfate on both Lana and volunteer grasses on a low fertility medusahead-infested site in Amador County, California. Similar results were obtained when nitrogen was applied to Lana vetch seeded in resident grasses at Sunol, California, as shown in Table 5.

Fertilization and management that increase the percentage of Lana usually decrease the percentage of annual grasses. Field observations show, however, that even when Lana contributes 30 to 40 percent of the total herbage, forage yields are increased, the percentage of desirable grasses is greater, and medusahead is suppressed. The earlier fall starting grasses such as soft chess *Bromus mollis* L., wildoats *Avena fatua* L., and ryegrass *Lolium multiflorum* Lam., are more compatible with Lana and

FIG. 2. Lana vetch makes rapid growth and forms a dense canopy during the late spring causing severe competition to annual grasses, particularly the late-developing medusahead.

Table 3. Crude protein (%) of Lana vetch samples from field plantings in western Oregon.[1]

Cooperator	Soil conservation districts	Date collected	Crude protein
Lester Perrin	N. Douglas	7/ 1/65	9.10
George Churchill	N. Douglas	7/ 8/66	9.54
Arthur Kopp	N. Douglas	7/28/64	10.48
Stanley Curyea	Yamhill	7/12/67	12.27
Pullman Farm	E. Multnomah	7/10/67	13.10
Jake Powell	N. Douglas	7/ 8/65	14.73

[1] Crude protein determined by Department of Agricultural Chemistry, Oregon State University.

Table 4. Two-year average production (lbs/acre, dry forage) of Lana vetch and volunteer grass as influenced by fertilizer treatment on the Henry Muller Ranch, Amador County, California.[1]

Treatment	Two-Year Average		
	Lana	Other	Total[2]
Non-Fertilized	60	1,044	1,104
200 lb/acre 0-45-0	882	1,287	2,169
400 lb/acre 0-20-0	1,001	1,455	2,456
450 lb/acre 16-20-0	144	3,656	3,800

[1] Auburn silt loam VIe4.
[2] 1961 and 1962 yield data.

consequently the percentage of these grasses in the herbage may be increased.

Summary

Lana vetch, an improved variety of woollypod vetch, offers much promise for controlling one of California and western Oregon's most serious range weeds—medusahead. Studies on the use of Lana vetch for medusahead control show that, where Lana is adapted, overseeding, annual fertilization with phosphate and sulfur, and deferred grazing are the keys to the suppression of medusahead by this self-perpetuating annual legume. Much of the medusahead-infested range is on land too rough or steep to permit mechanical seedbed preparation. Because Lana can be successfully established from direct seeding without seedbed preparation it offers a very practical method of controlling medusahead on rough terrain. Increased production and improved quality of forage from infested annual grass range are the result.

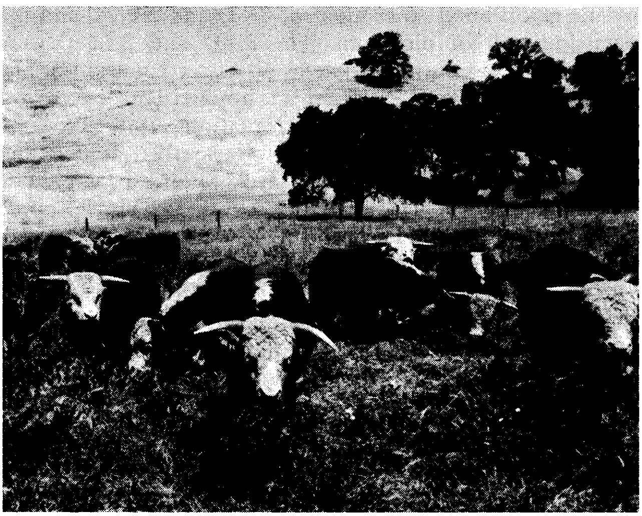


FIG. 3. Lana vetch is relished by livestock and good gains are obtained. It maintains its nutritive quality, averaging 11.54 percent crude protein after maturity.

Table 5. Three-year average production (lbs/acre, dry forage) of Lana vetch and volunteer grass as influenced by fertilizer treatment at Sunol, California.[1]

Treatment	Three-Year Average		
	Lana	Other	Total[2]
Lana only	1,319	2,327	3,646
Lana + 0-90-0	2,482	2,058	4,540
Lana + 32-40-0	1,875	3,495	5,370
Lana + 64-80-0	959	5,123	6,082

[1] Positas gravelly clay loam VIe3.
[2] 1961, 1962, and 1963 yield data.

Literature Cited

GORDON, AARON, AND A. W. SAMPSON. 1939. Composition of common California foothill plants as a factor in range management. Univ. of Calif. Bull. 627.

LUEBS, R. E., AND A. E. LAAG. 1963. Wimmera ryegrass and Lana vetch for forage on marginal grainland. J. Range Manage. 16:122–124.

MAJOR, J., C. M. MCKELL, AND L. J. BERRY. 1960. Improvement of Medusahead infested rangeland. Calif. Agr. Exp. Sta. Ext. Serv. Leaflet 123.

MILLER, H. W., O. K. HOGLUND, AND A. L. HAFENRICHTER. 1964. A range improvement program for Mediterranean climates. Proc. IX Int. Grassland Congr.

TURNER, ROBERT B., CHARLES E. POULTEN, AND WALTER L. GOULD. 1963. Medusahead—Threat to Oregon rangeland. Oregon State Univ. Special Report No. 149.

Effects of 2,4,5-T and Picloram on Broom Snakeweed in Arizona[1]

ERVIN M. SCHMUTZ AND DAVID E. LITTLE

Associate Range Management Specialist, Arizona Agricultural Experiment Station, Tucson; and Range Conservationist, Bureau of Land Management, Burns, Oregon.

Highlight

Foliar-spray and soil herbicidal treatments were made on broom snakeweed (*Gutierrezia sarothrae*) in a shortgrass vegetation type in central Arizona. Broom snakeweed was effectively controlled with foliar treatments of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) applied at 4 lb/acre in April and May. Foliar and soil (granular) treatments of 4-amino-3,5,6-trichloropicolinic acid (picloram) applied at 0.5 lb/acre were effective from February through March and September through December, respectively. Herbicide effectiveness was influenced by soil moisture and stage of plant growth, but apparently was not directly influenced by relative humidity, air temperature, soil temperature, time-of-day of application, or additives of glucose and boron. The effectiveness of 2,4,5-T was greatly increased by the addition of 10% diesel oil in the spray mixture when applied at the rate of 50 gpa. The effectiveness of 2,4-dichlorophenoxyacetic acid (2,4-D) on snakeweed was similar to that of 2,4,5-T.

Resumen

El estudio se llevó a cabo en un tipo de vegetación de zacates cortos en el centro del estado de Arizona tendiente a combatir "Broom snakeweed" (*Gutierrezia sarathrae*), una hierba tóxica abundante en los pastizales de Estados Unidos y México. La planta fue controlada efectivamente con la aplicación foliar de 4.0 lb/acre de 2,4,5-T durante los meses de abril y mayo, siendo su acción fuertemente aumentada agregando 10% de Diesel, similar resultado se obtuvo aplicando 0.5 lb/acre de Picloram en forma foliar en los meses de febrero y marzo. Igual dosis, pero de picloram granulado, fue efectivo de septiembre a diciembre. La efectividad del hervicida se vio influida por la humedad del suelo y época de crecimiento de las plantas.

Broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby) is an undesirable poisonous plant that has invaded or increased on millions of acres of depleted western rangelands, especially grasslands (Campbell and Bomberger, 1934; Forest Service, 1937; Humphrey, 1964; Jardine and Forsling, 1922; Nichol, 1952; Parker, 1939; Platt, 1959; Schmutz, Freeman, and Reed, 1968). Improvement of these ranges will usually involve some form of snakeweed control. A method that offers great promise is the use of herbicides. To develop an herbicide program, basic studies are needed to determine the most effective time and methods for application of the herbicides.

The objectives of this study were to determine the effects of the season, time-of-day, rate of application, and level of soil moisture on the susceptibility of broom snakeweed to 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 4-amino-3,5,6-trichloropicolinic acid (picloram). Also, the effectiveness of these herbicides was compared to 2,4-dichlorophenoxyacetic acid (2,4-D).

The Study Area and Methods

The study was conducted in Yavapai County, Arizona in a shortgrass vegetation type one mile south of Cordes, Arizona (Fig. 1). The area, once dominated by blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) and associated grasses (Humphrey, 1964, Nichol, 1952), was dominated by snakeweed. The study area was located on a shallow soil on a ridge at an elevation of 3800 ft. Slopes varied from 5 to 15%. The shallow soil, derived from schist and granite, was classified as a Balky gravelly loam.[2] Permanent wilting point (15 atm tension) was at 9.5% soil moisture.

Climatic data from Cordes shows that precipitation occurs in a summer–winter rainfall pattern and averages about 13 inches annually (Weather Bureau, 1937–1964). The wettest months are December to April and July to September. Mean monthly temperatures vary from a high of 75 F in July to a low of 47 F in January. The frost-free period averages 223 days.

The studies were conducted on 12 × 14-ft plots surrounded by 4-ft buffer strips. Treatments were randomized and replicated four times. Herbicides used were the propylene glycol butyl ether esters of 2,4-D and 2,4,5-T and the potassium salt of picloram. The 2,4-D and 2,4,5-T were applied as sprays in a 2% diesel oil–water emulsion at the rate of about 50 gpa. Picloram was applied both in a water spray (50 gpa) and as granules containing 10% active ingredient. The 2,4-D and 2,4,5-T were applied at the rates of 1 and 4 lb/acre and picloram at 0.5 and 2 lb/acre. The spray was applied at 35 psi with a 4-ft, two-nozzle, boom sprayer that produced a 7-ft spray swath. Granules were broadcast by hand. To insure uniform application, each plot was treated twice by applying half of the treatment each time. On the date of each application, the time of day, relative humidity, air temperature, and soil temperature were recorded. Also gravimetric soil moisture samples were taken at the 2- and 6-inch depths.

To determine the seasonal susceptibility of snakeweed to 2,4,5-T and picloram, applications were made during 1964 at 2- and 4-week intervals from April through September and 2-month intervals from October through March. Treatments were made near the middle of the day to reduce time-of-day differences in photosynthesis and translocation.

To determine the time-of-day effects of temperature, light intensity, humidity, and soil moisture on herbicide effectiveness, foliar applications of 2,4,5-T were made at 2-hour intervals during the day and at 4-hour intervals at night.

[1] Contribution from the Department of Watershed Management, Arizona Agricultural Experiment Station, University of Arizona Journal Article No. 1516. Received August 27, 1969; accepted for publication December 1, 1969.

Appreciation is expressed to the Bureau of Land Management for making available and fencing the site for this study and to the Dow Chemical Co., Midland, Michigan, for furnishing the herbicides used in the experiments.

[2] Personal communication from G. Wendt, Soil Scientist, Soil Conservation Service, Prescott, Arizona.

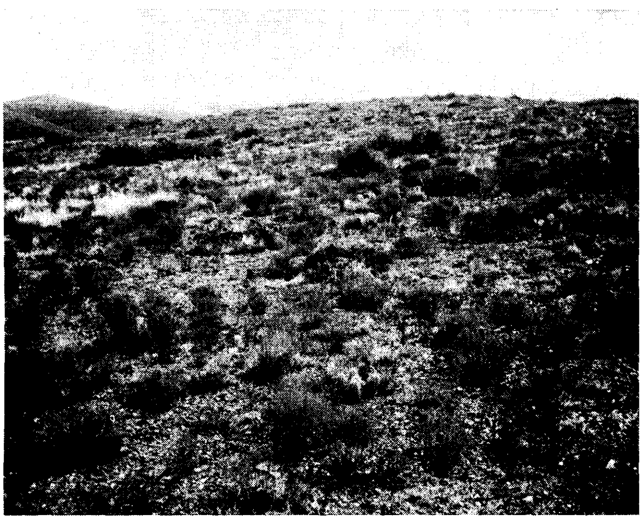


FIG. 1. General view of the study area near Cordes, Arizona. Note the dominant cover of snakeweed and scattered bunches of grass.

Treatments were made during one 24-hour period on September 3 and 4, 1964.

The effect of oil-carrier concentrations on herbicide absorption and effectiveness was determined by applying various amounts of No. 1 diesel oil with 2,4,5-T. The herbicide was applied in 0, 2, 10, and 50% (by volume) diesel oil–water emulsions. Treatments were made on August 13, 1964 during the middle of the day.

A comparison of the seasonal effectiveness of granulated and liquid forms of picloram was made by applying each form near the first day of April (spring), June (summer), September (fall), and December (winter).

The influence of sugar and boron additives on herbicide translocation and effectiveness on broom snakeweed was studied by applying 0, 50, and 500 ppm of borax (sodium tetraborate, $Na_2B_4O_7 \cdot 10H_2O$) in combinations with 0, 10, and 20% concentrations of glucose with both 2,4,5-T and picloram. Foliar applications were made during the middle of the day on August 13, 1964.

The effectiveness of different herbicides on snakeweed was compared by making foliar applications of 2,4-D, 2,4,5-T, and picloram on August 12, 1964.

Effects of all treatments were evaluated in April, 1965, by estimating the percentage of plants killed. Estimates were made on ten healthy plants selected at random before treatment on each plot.

Results

Seasonal Susceptibility.—The seasonal study showed that there were highly significant differences in the effectiveness of the different rates of 2,4,5-T and picloram applied as foliar sprays at different times of the year (Fig. 2). The 4-lb/acre rate of 2,4,5-T produced significant kill of snakeweed (45 to 72%) only in the spring months of April and May. Kill was not significant in the summer, fall or winter at the 4-lb rate or at any season of the year at the 1-lb rate.

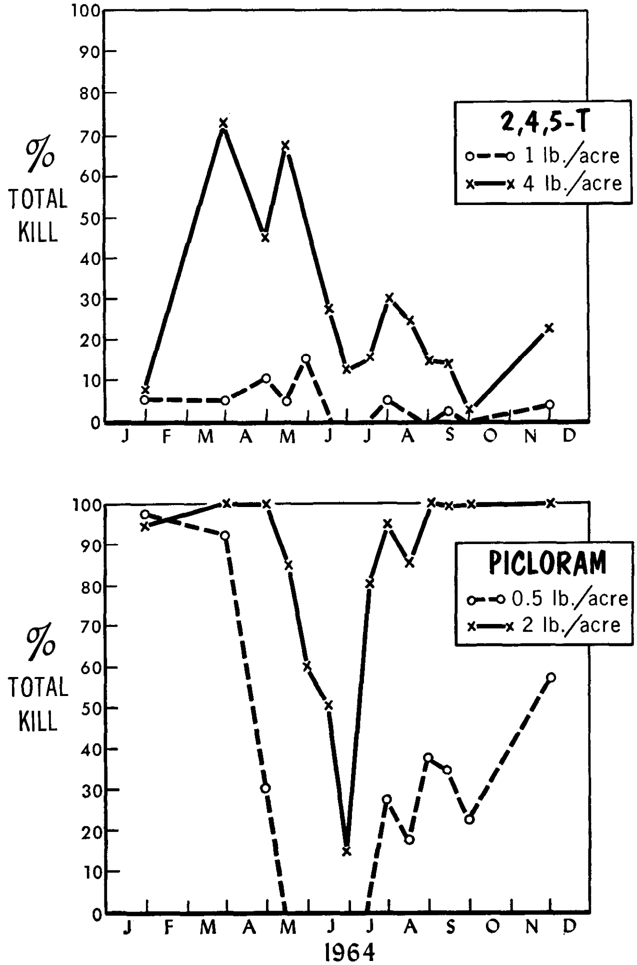


FIG. 2. Seasonal pattern of snakeweed susceptibility to foliar applications of 2,4,5-T and picloram.

Picloram was most effective during February and March, when both rates produced 95 to 100% kill of snakeweed, and least effective during June and July. The 2-lb rate produced near 100% kill in the fall and winter; kill at the 0.5-lb rate was generally less than 40% in the fall and 60 to 100% in the winter.

A comparison of the percentages of kill with seasonal soil moisture levels at the 2- and 6-inch depths (Fig. 3) showed that the two were correlated in part. The high rates of kill in the winter and spring by both rates of picloram decreased as soil moisture declined below the wilting percentage during late spring. With the rise in the soil moisture following the summer and fall rains percentage kill returned to a high level at the 2-lb rate but not at the 0.5-lb rate. Also, summer kill of burroweed by both rates of 2,4,5-T was lower than in the spring. These differences indicate that during the summer and fall some other factor besides soil moisture was limiting the effectiveness of the low rate of picloram and both rates of 2,4,5-T.

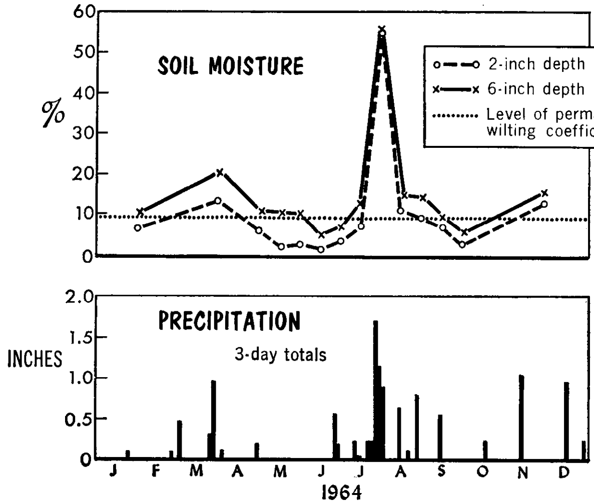


FIG. 3. Precipitation at Cordes, Arizona (Weather Bureau, 1964) and level of soil moisture at times of herbicide treatments.

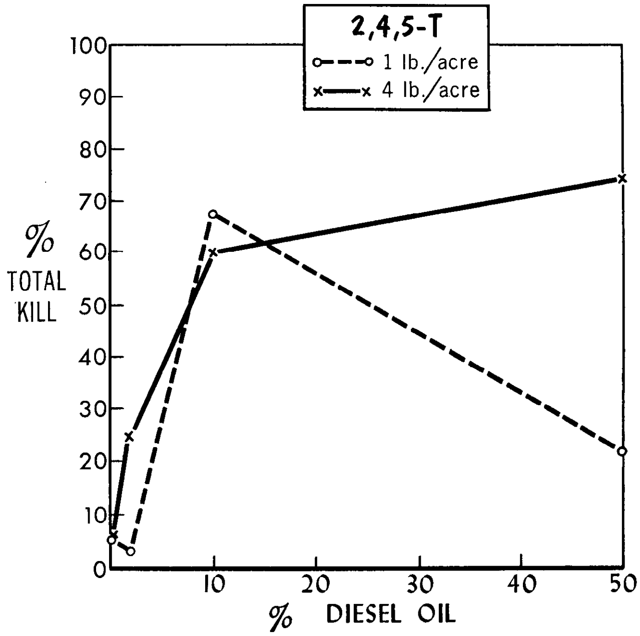


FIG. 4. Influence of the amount of diesel oil in the carrier on the effectiveness of 2,4,5-T on snakeweed.

A possible influence was the stage of plant growth. The percentages of plant kill by the 4-lb rate of 2,4,5-T were greatest during the spring flush of growth and lowest during the dormant periods of the spring drouth and the winter cold. Also, kills were lower during the summer-flowering and fall-seeding periods even though soil moisture was as high or higher than in the spring.

Plant responses to picloram were similar except that high plant kill resulted from winter applications at both rates and equally high plant kill resulted from late summer treatments at the high rate of treatment. The greater effect of winter treatments may have resulted from greater soil and root absorption (Hamaker et al., 1963) and slower decomposition, and consequently higher retention of the picloram in the plant after treatment which resulted in subsequent death loss during the spring growth season. The lower rate of kill in the summer and fall from the low rate of picloram appeared to be due to stage of growth differences. However, the high rate of picloram treatment appeared to mask effects due to stage of growth.

Comparison of relative humidity, air temperature, and soil temperature data with the percentages of plants killed at different seasons of the year produced no corresponding patterns that would indicate that these factors had any limiting influence on herbicide effectiveness in this study.

Time-of-Day Susceptibility.—The time-of-day study failed to show any significant difference in the effectiveness of 2,4,5-T when applied at different times of the day. This may have been due to the fact that the study was made when snakeweed was low in susceptibility to 2,4,5-T (Fig. 2).

Oil-Carrier Effects.—The oil-carrier study (Fig. 4) showed that the diesel oil concentration had a highly significant influence on the effectiveness of 2,4,5-T on snakeweed. The 10% concentration of oil significantly increased the effectiveness of 2,4,5-T over the 0 and 2% concentrations at both herbicide rates. A further increase in the oil concentration to 50% decreased the effectiveness of the herbicide at the 1-lb rate but increased it at the 4-lb rate. The 10% rate of diesel oil may have had a direct toxic effect on the snakeweed or may have increased the effectiveness of 2,4,5-T by facilitating its absorption through the stomata of the leaf or its translocation in the plant (Van Overbeek and Blondeau, 1954). The reason for the differential effect of the 50% rate of oil on the two rates of 2,4,5-T is not known.

Granulated vs Liquid Picloram.—Comparison of the granulated vs liquid forms of picloram on broom snakeweed showed that differences were highly significant and that the effects varied by rate and season of application (Fig. 5).

At the 0.5-lb rate, the granules had a greater mean effectiveness (64% kill) than the liquid (47% kill), but at the 2-lb rate the liquid (90% kill) was more effective than the granules (83% kill). Comparisons by dates showed that the low rate of liquid was more effective in the spring than the low rate of granules, but the opposite was true in the summer, fall, and winter. At the high rate the seasonal effectiveness of the liquid was always equal to or greater than that of the granules. With both granules and liquid, the high rate was more effective than the low rate, except in the fall and winter when differences between the granular rates were not significant.

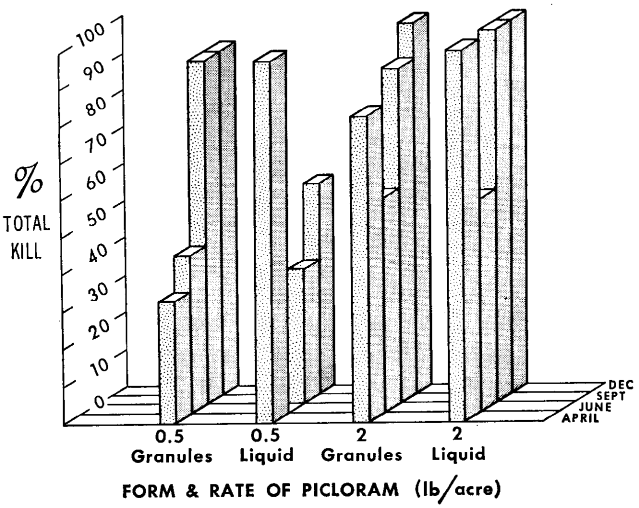


FIG. 5. Influence of season of application on the effectiveness of various forms and rates of picloram in controlling snakeweed.

In all cases the summer applications were least effective. These applications were made during the driest time of the year, approximately six weeks prior to the start of the summer rains. The reduced effectiveness of the herbicide during the summer is believed to have been due to greater sorption of the herbicide by the soil and its degradation by ultraviolet light (Anonymous, 1965).

Other Studies.—Kill of snakeweed from the herbicide–boron–sugar treatments varied from 0 to 95% and followed no consistent pattern. The variable results were apparently due to a rain soon after the treatments that washed off portions of the spray before it could be absorbed by the plants.

In the comparison-of-herbicide study, plant kill by the 4-lb/acre rate of 2,4-D (35%) on August 12 was not significantly greater than the 4-lb rate of 2,4,5-T (25%), plant-kills by the 1-lb treatments were less than 2%. In contrast plant kill by the 2-lb rate of picloram (85%) was significantly greater than that by the 4-lb treatments of 2,4-D or 2,4,5-T and plant kill by the 0.5-lb treatment of picloram (18%) was greater than that by the 1-lb rate of 2,4-D or 2,4,5-T.

Discussion

These studies showed that in central Arizona broom snakeweed can be effectively controlled with 4-lb/acre foliar treatments of 2,4,5-T applied in April and May, with 0.5 lb/acre foliar treatments of picloram from February through March, or with 0.5 lb/acre granular applications of picloram from September through December. Treatment effects were influenced by soil moisture conditions and stage of plant growth, but apparently were not directly influenced by relative humidity, air temperature, soil temperature, time-of-day of application, or additives of glucose and boron. Addition of 10% diesel oil in the 2,4,5-T spray, when applied at 50 gpa, increased herbicide effectiveness. The effectiveness of 2,4-D was similar to that of 2,4,5-T.

Picloram was 2 to 4 times more toxic to broom snakeweed than 2,4-D or 2,4,5-T and the season of susceptibility extended over a much longer period. These results were similar to findings on three Chihuahuan Desert shrubs in Arizona (Schmutz, 1967). However, the season of susceptibility contrasted strikingly since the Chihuahuan shrubs were more susceptible in the summer and fall and snakeweed in the winter and spring. The longer season of susceptibility to picloram as compared to 2,4,5-T was probably due to the greater translocation of picloram under moisture stress (Merkle and Davis, 1967).

Literature Cited

ANONYMOUS. 1965. Tordon information manual, p F-1 to F-3 (revised). The Dow Chemical Co., Midland, Michigan.

CAMPBELL, R. S., AND E. H. BOMBERGER. 1934. The occurrence of *Gutierrezia sarothrae* on *Bouteloua eriopoda* ranges in southern New Mexico. Ecology 15:49–61.

FOREST SERVICE. 1937. Range plant handbook. U.S. Gov. Print. Office, Washington, D.C.

HAMAKER, J. W., H. JOHNSTON, R. T. MARTIN, AND C. T. REDEMANN. 1963. A picolinic acid derivative: a plant growth regulator. Science 141:363.

HUMPHREY, R. R. 1964. Arizona range resources. II Yavapai County. Arizona Coop. Ext. Service, Agr. Exp. Sta. Bull. A-35. 55 p. (Reprint of Arizona Agr. Exp. Sta. Bull. 229 dated 1950).

JARDINE, J. T., AND C. L. FORSLING. 1922. Range and cattle management during drought. U.S. Dep. Agr. Bull. 1031. 84 p.

MERKLE, M. G., AND F. S. DAVIS. 1967. Effect of moisture stress on absorption and movement of picloram and 2,4,5-T in beans. Weeds 15:10–12.

NICHOL, A. A. 1952. The natural vegetation of Arizona. Arizona Agr. Exp. Sta. Tech. Bull. 127. p. 189–230.

PARKER, K. W. 1939. The control of snakeweed in the Southwest. Southwestern Forest and Range Exp. Sta. Res. Note 76. 4 p.

PLATT, K. B. 1959. Plant control—some possibilities and limitations II. Vital statistics of range management. J. Range Manage. 12:194–200.

SCHMUTZ, E. M. 1967. Chemical control of three Chihuahuan Desert shrubs. Weeds 15:62–67.

SCHMUTZ, E. M., B. N. FREEMAN, AND R. E. REED. 1968. Livestock-poisoning plants of Arizona. The Univ. of Arizona Press, Tucson. 176 p.

VAN OVERBEEK, J., AND R. BLONDEAU. 1954. Mode of action of phytotoxic oils. Weeds 3:55–56.

WEATHER BUREAU. 1937–1964. Climatological data. U.S. Dep. of Commerce, Washington, D.C. (Monthly issues).

Effect of Burning and Clipping on Big Bluestem Reserve Carbohydrates[1]

CLENTON E. OWENSBY, GARY M. PAULSEN, AND JAY DEE McKENDRICK

Assistant Professor, Associate Professor, and Research Assistant, Department of Agronomy, Kansas State University, Manhattan.

Highlight

Carbohydrate content of rhizomes and stem bases of big bluestem (*Andropogon gerardi* Vitman) at different times during the growing season were measured on plots with different clipping and burning treatments. Big bluestem on plots burned May 1 had higher herbage yields, percent nitrogen, and total nitrogen in forage than that on unburned plots. Rapid vegetative growth during mid-July reduced carbohydrate percentages in rhizomes and stem bases of big bluestem. Burning did not affect final storage of carbohydrate on unclipped plots, but, in general, it reduced carbohydrate reserves on clipped plots. Late season clipping reduced carbohydrate reserves more than early season clipping.

Range species must survive nonphotosynthetic periods during the winter and following herbage removal. Survival is accomplished by prior elaboration and accumulation and subsequent metabolism of reserve carbohydrate substances (i.e., sugars, starches, dextrins, fructosans). Reserve carbohydrate content of range plants is therefore a critical factor in plant growth and survival.

Carbohydrate reserves are stored primarily in roots, rhizomes, and stem bases of range grasses (Graber et al., 1927; Weinmann, 1948). Fluctuations in reserve carbohydrate levels in relation to phenologic development have been well documented (Graber et al., 1927; McCarty, 1935, 1938; Aldous, 1930; Sampson and McCarty, 1930; Weinmann, 1944, 1948). Carbohydrate reserve levels in storage tissues decrease rapidly concurrent with new growth following a dormant period or defoliation. When sufficient photosynthetic tissue has been produced so that carbohydrate production exceeds growth needs, reserve carbohydrate levels increase. Accumulation of reserve carbohydrates continues until defoliation, phenologic change, or dormancy necessitate carbohydrate utilization above normal growth and maintenance requirements. Seed stalk production frequently decreases carbohydrate reserves temporarily. During dormant periods, respiration gradually lowers reserves and, following dormancy, initiation of new growth rapidly depletes reserve levels.

Any factor affecting photosynthesis affects reserve carbohydrate accumulation. Cutting or grazing native prairie grasses during the growing season removes photosynthetic tissues and necessitates use of accumulated organic substances for new growth. Aldous (1930) showed clipping four True Prairie species reduced carbohydrate accumulation. Frequent clipping, particularly late in the growing season, decreased carbohydrate reserves necessary for survival during the dormant period and subsequent post-dormancy regrowth (McCarty, 1935; Kinsinger and Hopkins, 1961; Sprague and Sullivan, 1950; Wolf, 1967).

Literature is lacking on the influence of burning on carbohydrate reserves in grasses. Anderson (1951) suggested that reduction in carbohydrate reserves could follow intensive grazing encouraged by burning. Burning alone without grazing did not affect the seasonal cycle or the level of reserves in *Themeda triandra* (Daitz, 1954). Burning, however, affects phenologic development of prairie species. Reports in True Prairie vegetation have shown increased early growth, increased seed stalk production, and changes in chemical composition as a result of burning (Ehrenreich and Aikman, 1963; Aldous, 1934; Hensel, 1923). Those changes in growth and development should be reflected in the carbohydrate reserve cycle.

The study was to determine the effect of late spring burning and clipping at different dates on carbohydrate reserves, herbage yield, and herbage nitrogen composition of big bluestem (*Andropogon gerardi* Vitman).

Materials and Methods

Plots for the 1967 study were located in a 7-year-old stand of Kaw big bluestem rested during the entire 1966 growing season. Unburned plots and plots burned May 1, 1967, had five treatments imposed: unclipped or clipped June 1, July 1, August 1, or September 1. Individual plots were 5 by 8 ft and were replicated twice in a randomized complete block design. Each clipping was made at a 2-inch stubble height with a sickle-bar mower. Dry weight (70 C) herbage yields were determined for each clipping. Nitrogen content of the herbage was determined by the Kjeldahl method (Hiller et al., 1948) after grinding the samples to 40-mesh size.

Five to ten big bluestem tillers, including their basal node areas and attached rhizomes, were collected from unclipped, burned and unburned plots at 2-week intervals from April 15 through September 30, and from clipping-treatment plots at 2-week intervals after clipping occurred and through September 30. Soil, roots, and dead organic debris were removed from the samples by cold water washing. Elongated culms were removed 2 inches above the uppermost basal node.

[1]Contribution No. 1107. Department of Agronomy, Kansas Agricultural Experiment Station. Received September 2, 1969; accepted for publication November 11, 1969.

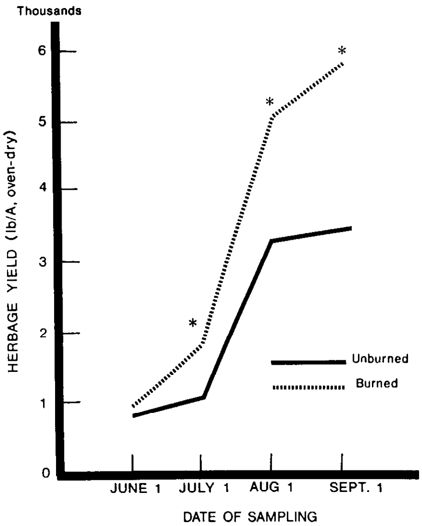


FIG. 1. Herbage yield (lb/A, oven-dry) of big bluestem clipped at different dates from burned and unburned plots. Asterisk above a given clipping date indicates statistically significant difference due to burning treatment (P < .05).

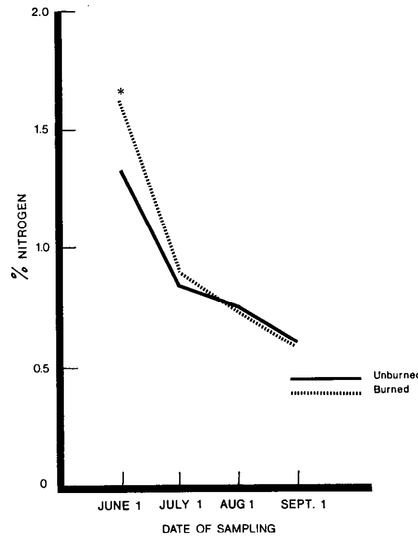


FIG. 2. Percent nitrogen in big bluestem herbage clipped at different dates. Asterisk above a given clipping date indicates statistically significant difference due to burning treatment (P < .05).

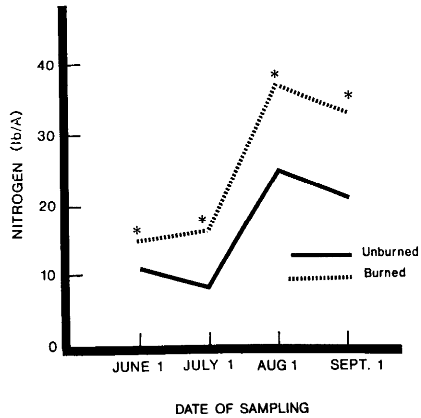


FIG. 3. Total nitrogen (lb/A) in big bluestem herbage clipped at different dates. Asterisk above a given clipping date indicates statistically significant difference due to burning treatment (P < .05).

The cleaned samples were oven dried at 70 C, ground in a Wiley mill (40-mesh screen), and stored in glass bottles before determining total available carbohydrates (TAC).

Five hundred mg of oven-dry tissue were refluxed in 0.2 N sulfuric acid for one hour to hydrolyze nonstructural polysaccharides to reducing sugars (Smith et al., 1964). Following hydrolysis, the solutions were filtered through Whatman no. 42 paper and neutralized with 2.5 N NaOH. Glucose equivalent was determined on duplicate 10-ml sample aliquots by the Shaffer-Somogyi titration technique outlined by Heinze and Murneek (1940). Water blanks and 1 mg and 2 mg glucose standards were titrated daily as references. Starch equivalent was calculated from the titrated glucose equivalent and reported as percentage TAC.

Precipitation was only slightly above normal in 1967 and temperatures near established norms.

Results and Discussion

Big Bluestem Herbage. Burned plots produced significantly more herbage than unburned plots at all dates (Fig. 1). Production on burned and unburned plots by June 1 did not differ significantly. but the increase in herbage yield from burned plots above that from unburned plots became greater on successively later clipping dates. The increase due to burning agreed with experiments in wetter sections of the True Prairie (Hadley and Kieckhefer, 1963; Kucera and Ehrenreich, 1962), but not with prior experimental work at Manhattan, Kansas (Aldous, 1934; McMurphy and Anderson, 1963). The increase in herbage yield on burned plots in this study may have been due to removal of excessive mulch. Dix (1960) reported herbage yields were reduced by mulch accumulation following burning. Weaver and Rowland (1952) similarly indicated excess mulch reduced yield. Another possible explanation could be differential species response to burning. Most studies have dealt with native prairie containing mixed stands of several species. Pure stands of certain species might yield more under burning and others might yield less.

Kucera and Ehrenreich (1962) speculated that increases in herbage yield late in the growing season on burned central Missouri prairie were due largely to increased flower stalk production. Flower stock production increased on burned plots in this study, but flowering was so sparse that increased production from flower stalks was insignificant.

Nitrogen in Herbage. Nitrogen percentage was higher in big bluestem herbage from burned plots than from unburned plots at the June 1 clip date (Fig. 2). Nitrogen percentages did not differ between burning treatments at other clipping dates. However, nitrogen concentration declined each successive clipping date, so only approximately one-third the June 1 percentage was present by September 1. That decline indicated the necessity for earlier clipping for good quality prairie hay.

Total nitrogen in big bluestem dry matter was higher on burned plots than on unburned plots at all clip dates (Fig. 3). The difference on June 1 was due primarily to increased nitrogen concentration in herbage from burned plots but, as the growing season progressed, increased herbage growth usually resulted in higher nitrogen amounts per acre. Increased dry matter production during June did not increase total nitrogen yield, however, since percent nitrogen in the forage dropped drastically. High growth rate in July increased total nitrogen per acre. Decreased nitrogen percentage in big bluestem during

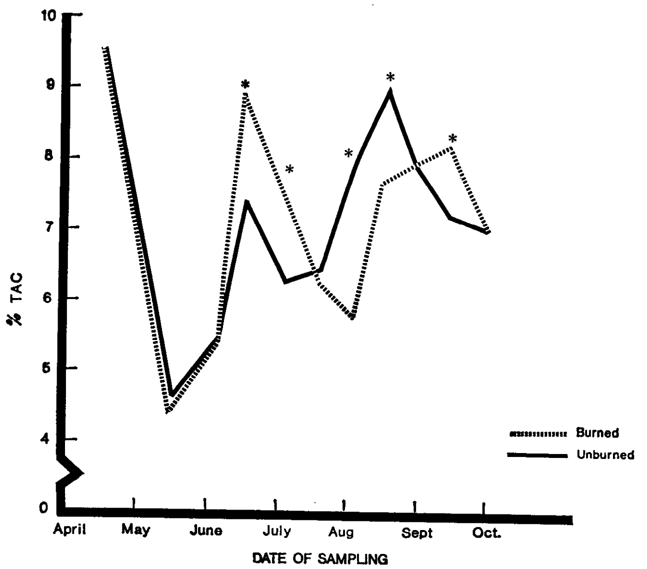


FIG. 4. Percent total available carbohydrates (TAC) in rhizomes and stem bases on different dates for unclipped, burned or unburned, big bluestem. Asterisk above a given date indicates statistically significant difference due to burning treatment (P < .05).

August decreased the total nitrogen yield per acre September 1. Murneek (1932) attributed decreased herbage N yields to movement of nitrogen into roots and rhizomes as maturity approached. That was supported by work in South Dakota demonstrating that prairie hay left standing in the field increased little in biomass, but decreased appreciably in nitrogen content (Moxon et al., 1951).

Carbohydrate Reserves. Reserve carbohydrates in unclipped big bluestem rhizomes and stem bases declined rapidly during the early portion of the growing season (Fig. 4). Reserve accumulation was minimal by mid-May and replenishment of reserves began by early June. Carbohydrate reserves were slightly higher on burned plots than on unburned plots in mid-June. Herbage growth increased more during July than during any other month and, concurrently, carbohydrate reserves dropped markedly during that period of rapid growth. Growth needs for carbohydrates likely exceeded photosynthetic productivity forcing use of reserves. Several reports (Smith and Jewiss, 1966; Sprague and Sullivan, 1949) indicate that high temperatures depress reserves of grasses. Typically high July temperatures in the True Prairie region might similarly cause some reduction in carbohydrate accumulation. Depletion of carbohydrate reserves during July continued into August and was greater on burned plots than on unburned plots. The greater reserve use on burned plots was probably due to a higher growth rate on those plots than on unburned plots during August. Carbohydrate reserves were replenished on both burned and unburned plots during August and declined during September. Reserve carbohydrate depletion at that time was not due to flowering since all plants remained vegetative on unburned plots and less than 1% flowered on burned plots. No herbage yield data were obtained for September but some growth during that period probably decreased carbohydrate accumulation. Differences in carbohydrate reserves between burned and unburned plots during the growing season disappeared by October 1.

Big bluestem plants clipped June 1 accumulated less carbohydrate reserves in rhizomes and stem bases than unclipped plants during the succeeding month (Fig. 5). Accumulation of reserves on June clipped plots throughout the remainder of the growing season, however, was similar to that on unclipped plots. Burned plots were lower in carbohydrate storage on four of eight sampling dates following June clipping. Maximum carbohydrate accumulation occurred during mid-August to early September with some depletion of reserves during the later portion of the growing season. Depletion of reserves in mid-July in big bluestem was greater from plots clipped July 1 than from unclipped plots. Contrary to June clipping results, carbohydrate reserves were higher in plants from burned plots soon after clipping, but were lower in

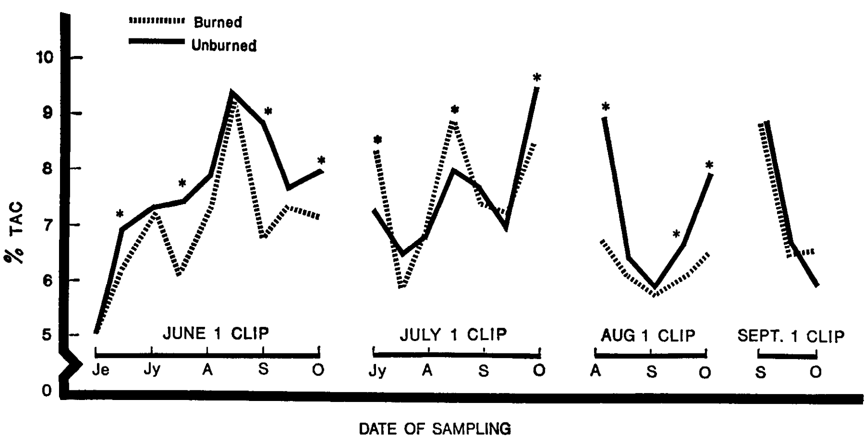


FIG. 5. Percent total available carbohydrates (TAC) in rhizomes and stem bases of big bluestem following clipping at different dates. Asterisk above a given date indicates statistically significant difference due to burning treatment (P < .05).

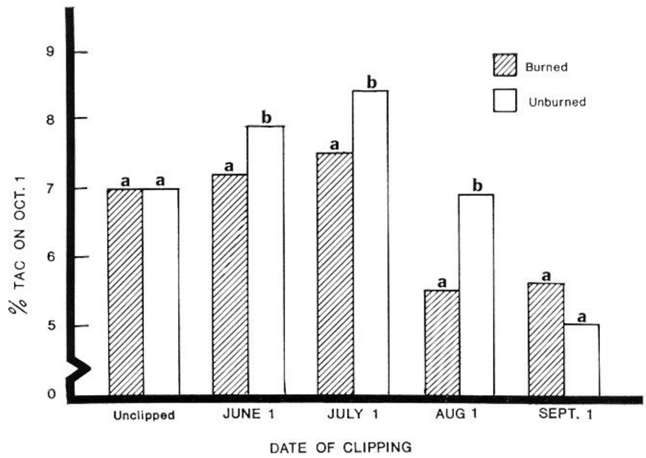


FIG. 6. Percent total available carbohydrates (TAC) in rhizomes and stem bases of big bluestem on October 1 following clipping at indicated dates. Percent TAC for a given clipping date with the same letter above the bar does not differ significantly with respect to burning treatment ($P < .05$).

plants from burned plots at the close of the growing season.

August clipping resulted in a marked decline in carbohydrate reserves in big bluestem rhizomes and stem bases on burned and unburned plots (Fig. 5). Rhizomes and stem bases of plants on unburned plots recovered their reserve concentrations by the close of the growing season, but those of plants on burned plots did not replenish reserves to the level of unclipped plants. Clipping on September 1 accelerated the reserve decline that occurred on unclipped plots during September. No difference in reserves existed between burned and unburned plots during September on plots clipped September 1. Carbohydrate reserves in plants remained much lower from plots clipped September 1 than from unclipped plots at the close of the growing season.

Plant carbohydrate reserves at the onset of dormancy have been shown to be important in herbage production the following growing season. It appeared that the later in the growing season that clipping occurred, the lower were reserves for use during winter dormancy and subsequent spring regrowth (Fig. 6). Burning lowered reserves in plants from plots clipped on June 1, July 1, and August 1, but not on September 1, to levels below those in plants from unburned plots clipped on the same dates. Carbohydrate reserves in plants were higher from unburned plots clipped in June and July than from unclipped, unburned plots which indicated that early season clipping and subsequent rest may be beneficial rather than harmful to warm-season plant communities.

Data from this one-year study indicate hay cutting date for bluestem meadows would lie somewhere between July 1 and August 1. Date of mowing studies reported by Owensby and Anderson (1969) in a bluestem meadow showed herbage yields to be highest over a six-year period from plots clipped August 1 compared with clipping the first of June, July, September, October, and November. Figure 7 shows the effects of September 1 clipping on botanical composition in relation to July 1 or August 1 clipping. The forb invading September 1 clipped plots was showywand goldenrod (*Solidago speciosa* Nutt.), whose life cycle was completed before September 1 and which did not regrow following clipping. Clipping on September 1 was advantageous to showywand goldenrod since the major dominant species, big bluestem, was weakened due to lowered carbohydrate reserves.

Previously reported carbohydrate reserve studies in warm-season grasses have not shown declines associated with rapid growth following the initial reserve depletion in early summer (Cook, 1966). That decline in reserves with high growth rate may have implications in grazing management systems. Grazing systems using the same pasture intensively late in the growing season year after year would likely reduce herbage yields and cause changes in botanical composition to less desirable species. Such systems would be more likely to deplete reserves

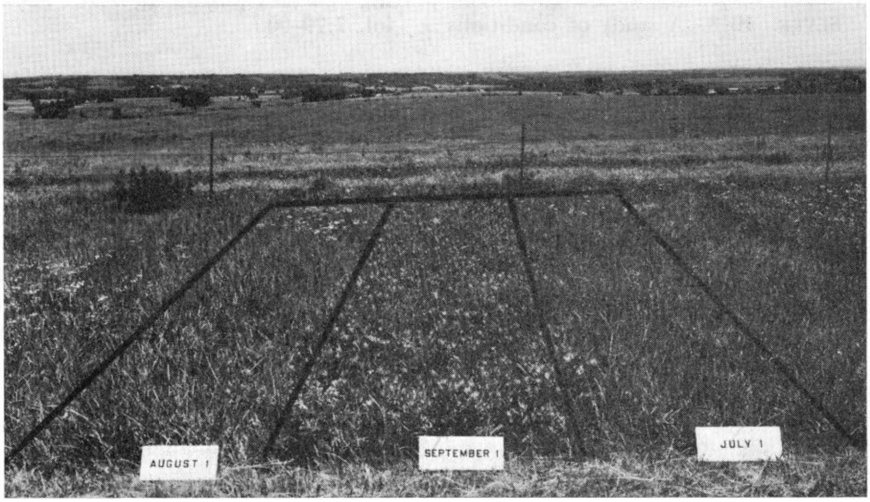


FIG. 7. Appearance of bluestem plots clipped at indicated dates for six years.

and degrade burned range than unburned range.

References Cited

Aldous, A. E. 1930. Effect of different clipping treatments on the yield and vigor of prairie grass vegetation. Ecology 11:752–759.

Aldous, A. E. 1934. Effect of burning on Kansas bluestem pastures. Kansas Agr. Exp. Sta. Tech. Bull. 38. 65 p.

Anderson, K. L. 1951. The effects of grazing management and site condition on Flint Hills bluestem pastures in Kansas. Unpbl. Ph.D. Thesis. Univ. Nebr. Lincoln, Nebr. *In* Herbel, C. H. 1954. The effects of date of burning on native Flint Hills range land. M.S. thesis Kansas Sta. Univ., Manhattan, Kansas.

Cook, C. W. 1966. Carbohydrate reserves in plants. Utah Agr. Exp. Sta. Resources Series 31. 47 p.

Daitz, J. 1954. Available carbohydrate reserves in the roots of *Themeda triandra* from a seasonal burn experiment at Bethal. Rep. Frankenwald Fld. Res. Sta. Univ. Witwaterstrand 1954. 27–29 mimeo. *In* Weinmann, H. 1961. Total available carbohydrates in grasses and legumes. Herb. Abstr. 31:255–261.

Dix, R. L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. Ecology 41: 49–56.

Ehrenreich, J. H., and J. M. Aikman. 1963. An ecological study of the effect of certain management practices on native prairie in Iowa. Ecol. Monog. 33:133–137.

Hiller, A., J. Plazin, and D. D. Van Slyke. 1948. A study of conditions for Kjeldahl determination of nitrogen in proteins. J. Biol. Chem. 176: 1401–1420.

Graber, L. F., H. T. Nelson, W. A. Luekel, and W. B. Albert. 1927. Organic food reserves in relation to the growth of alfalfa and other perennial herbaceous plants. Wisconsin Agr. Exp. Sta. Res. Bull. 80. 128 p.

Hadley, E. B., and B. J. Kieckefer. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 44:389–395.

Hensel, R. L. 1923. Effect of burning on vegetation in Kansas pastures. J. Agr. Res. 23:631–644.

Kinsinger, F. E., and H. H. Hopkins. 1961. Carbohydrate content of underground parts of grasses as affected by clipping. J. Range Manage. 14: 9–12.

Kucera, C. L., and J. H. Ehrenreich. 1962. Some effects of annual burning on central Missouri prairie. Ecology 43:334–336.

McCarty, E. C. 1935. Seasonal march of carbohydrates in *Elymus ambiguus* and *Muhlenbergia gracilis* and their reaction under moderate grazing use. Plant Physiol. 10:727–738.

McCarty, E. C. 1938. The relation of growth to the varying carbohydrate content in mountain brome. U.S. Dep. Agr., Tech. Bull. 598. 24 p.

McMurphy, W. E., and Kling L. Anderson. 1963. Burning bluestem—forage yields. Trans. Kansas Acad. Sci. 66:49–51.

Moxon, A. L., G. Gastler, G. E. Staples, and R. M. Jordan. 1951. Grass hay at its best. South Dakota Agr. Exp. Sta. Bull. 405. 24 p.

Murneek, A. E. 1932. Growth and development as influenced by fruiting and seed formation. Plant Physiol. 7:79–90.

Owensby, C. E., and K. L. Anderson. 1969. Effects of clipping at different dates on loamy upland bluestem range. J. Range Manage. 22:351–354.

Sampson, A. W., and E. C. McCarty. 1930. The carbohydrate metabolism of *Stipa pulchra*. Hilgardia 5:60–100.

Smith, D., G. M. Paulsen, and C. A. Raguse. 1964. Extraction of total available carbohydrates from grass and legume tissue. Plant Physiol. 39:960–962.

Smith, D., and O. R. Jewiss. 1966. Effects of temperature and nitrogen supply on the growth of timothy (*Phleum pratense* L.). Ann. Appl. Biol. 58:145–157.

Sprague, V. G., and T. Sullivan. 1950. Reserve carbohydrates in orchard grass clipped periodically. Plant Physiol. 25:92–102.

Sullivan, J. T., and V. G. Sprague. 1949. The effect of temperature on the growth and composition of the stubble and roots of perennial ryegrass. Plant Physiol. 24:706–719.

Weaver, J. E., and N. W. Rowland. 1952. Effects of excessive natural mulch on development, yield and structure of native grassland. Bot. Gaz. 114:1–19.

Weinmann, H. 1944. J. S. Afr. Bot. 10:37–54. *In* Weinmann, H. 1952. Carbohydrate reserves in grasses. Proc. 6th Inter. Grassl. Congr. 1: 655–660.

Weinmann, H. 1948. Underground development and reserves of grasses: A review. J. Brit. Grassl. Soc. 3:115–140.

Wolf, D. D. 1967. Assimilation and movement of radioactive carbon in alfalfa and reed canarygrass. Crop Sci. 7:317–320.

1970 Intermountain Forest Fire Research Council
Missoula, Montana. October 27, 28, 29, 1970.

A three-day symposium on **"The Role of Fire in the Forests of the Intermountain West"** being sponsored by the Intermountain Fire Research Council. The symposium will have 4 main parts: 1) Natural role of fire, 2) man's impact, 3) fire management direction, and 4) conclusions.

Predicted Forage Yield Based on Fall Precipitation in California Annual Grasslands[1]

ALFRED H. MURPHY

Specialist and Superintendent, Hopland Field Station, University of California, Hopland.

Highlight

The initiation of fall forage growth in the California annual grasslands is dependent upon the first half-inch of effective rainfall. Annual yield of this forage is influenced by the amount of precipitation received by the third week in November. At that time a determination can be made as to whether the expected annual production will be low, medium, or high. A coefficient of correlation value (r = .70), significant at the 1% level, was obtained between yield and total rainfall through November 20.

The forage yields on California annual grasslands differ considerably from one year to the next. A factor contributing to this variation is the date the annual plant seeds begin to germinate. This, in turn, depends upon the timing of the fall precipitation. Early estimates of expected annual forage production would be useful in planning range livestock grazing operations. With our present knowledge, predicting the annual forage yield before the growing season is more than half completed is unreliable.

Forage estimate systems based on precipitation data have been devised for various areas of North America. In the Great Plains region Rogler and Haas (1947) obtained a highly significant correlation coefficient (r = .76) for April–July precipitation and forage yield for the same season on a native sod of mixed prairie type. Stitt (1958) obtained high correlations (r = .67 to .93) between yield and April–May rainfall in a 15-inch rainfall area. Smoliak (1956) reported a highly significant correlation coefficient (r = .859) between yield and May–June precipitation in an Alberta, Canada study. In the Sandhills range type of Nebraska, Dahl (1963) found that the total precipitation in the two previous years had a significant influence on yield of grass during the spring growth period. Further west, in the Rocky Mountain states, Blaisdell (1965) noted that yield was well correlated with total precipitation in the nine-month period immediately preceding the growing season. From yield and precipitation data for semiarid ranges in Oregon, Utah, and Idaho, Sneva and Hyder (1962) developed a method, based on medium precipitation and herbage yield, for range operators to use to forecast herbage production in eastern Oregon.

In South Australia, where climate and vegetation is similar to California, Trumble and Cornish (1936) showed that rainfall at certain periods rather than total annual rainfall determined pasture yield. A high significant correlation between yield and rainfall was strongest for the April–June period (October–December in the northern hemisphere), coinciding with early stages of seasonal growth.

The purpose of this study was to determine if precipitation might be used as a basis for early forecasting of herbage yields on California ranges.

Study Area and Methods

Yield and precipitation data over a 16-year period were available for an annual range at the University of California's Hopland Field Station. This station is located approximately 40 miles inland from the coast at 39° N latitude, in a typical California foothill rangeland area. Average seasonal precipitation is 35 inches. Normally, the growing season starts in the latter part of October and is concluded by late May. In January the mean minimum temperature is 33 F and the mean maximum is 54 F. Average dates of the first and last freezes are November 15 and March 15, respectively (Elford and McDonough, 1963). The grasses are usually dry by mid-May.

The range pastures used were grazed by sheep both before and during the study. The elevation of the pastures varies between 600 and 1200 feet in an area of about 1000 acres. The herbaceous vegetation consists of annual native and introduced grasses and forbs. The more common genera of grasses are *Bromus*, *Festuca*, *Avena*, and *Hordum*. The forbs include *Erodium*, *Trifolium*, *Lotus*, and *Baeria*. The range is also characterized by scattered trees of the *Quercus* genus, both evergreen and deciduous types.

Eleven soil series are represented in the range area, the most prominent being the Sutherlin (Gowans, 1958).

In 1953, six pastures with the most grazing use during the winter–spring growing season, were selected for sampling. Six 0.001-acre exclosures were placed in each pasture. Before the start of each successive growing season, the exclosures were moved to new locations within the area. At the conclusion of the growing season, samples of the dry forage were taken from inside the exclosures.

Precipitation was measured at the 800-foot elevation, using a standard Weather Bureau 8-inch, nonrecording gage. Readings were made daily at 8 AM for the previous 24-hour period.

Discussion and Results

The annual dry weight forage yield during the 16-year study varied from a low of 900 pounds to a high of 3500 pounds per acre. The yields reflect the interaction of temperature, precipitation, and time of germinating rainfall. The seeds of the grassland plants respond readily to moisture, and

[1] Received October 27, 1969; accepted for publication April 18, 1970.

Table 1. Annual yield and accumulated effective precipitation (inches) totals for 1952–53 through 1967–68 growing years. Hopland Field Station.

			Precipitation													
Year	Yield group[1]	Yield (lb./acre)	Nov. 1	Nov. 5	Nov. 10	Nov. 15	Nov. 20	Nov. 25	Nov. 30	Dec. 31	Jan. 31	Feb. 28	Mar. 31	Apr. 30	May 31	Total season
1954–55	L	900	.7	.7	2.9	6.3	6.6	6.6	6.6	13.5	17.1	19.2	19.7	23.6	23.6	23.6
1955–56	L	1200	.4	.5	.5	1.5	3.1	4.8	4.8	24.2	39.3	47.3	48.2	49.7	50.4	50.5
1956–57	L	1300	3.0	3.1	3.1	3.1	3.1	3.1	3.1	3.8	10.9	19.3	22.9	25.5	29.2	29.3
1958–59	L	1700	0	0	.4	.7	1.4	1.4	1.4	3.1	15.2	23.3	25.0	25.5	25.5	25.5
1959–60	L	1700	2.1	2.1	2.1	2.1	2.1	2.1	2.1	3.5	9.3	18.6	24.3	25.8	28.0	28.0
1961–62	L	1300	.4	.4	.4	.4	1.2	6.9	8.1	12.6	14.1	25.0	29.9	30.5	31.1	31.1
1952–53	M	2000	0	0	0	2.7	2.7	2.7	2.7	19.9	30.8	31.1	35.2	38.3	40.0	40.7
1953–54	M	1800	1.7	1.7	2.9	6.3	6.8	9.1	9.1	9.9	22.4	27.7	33.4	36.1	36.1	37.2
1960–61	M	2200	.8	.8	.9	3.2	3.6	5.2	6.2	14.0	18.5	22.4	28.3	29.8	30.6	30.7
1965–66	M	2100	0	0	.9	5.8	7.6	9.1	9.6	14.5	24.0	27.4	29.1	30.2	30.4	30.6
1967–68	M	2200	2.0	2.1	2.5	3.6	3.7	3.7	4.2	10.5	20.4	25.1	29.7	30.3	31.0	31.1
1957–58	H	2800	9.7	9.7	10.0	10.9	11.2	11.2	11.2	16.9	25.9	45.4	53.0	59.0	59.6	60.4
1962–63	H	2800	9.3	9.3	9.5	9.5	9.6	9.6	11.7	15.7	20.1	25.0	32.0	39.0	40.2	40.3
1963–64	H	3400	3.7	4.8	6.3	8.0	9.4	10.3	10.3	12.8	19.3	19.6	22.2	23.1	23.9	24.4
1964–65	H	2600	3.0	3.5	7.8	9.0	9.0	9.6	10.8	27.0	35.5	36.8	37.8	43.0	43.0	43.0
1966–67	H	2600	0	0	.8	2.5	7.9	9.0	9.5	17.3	27.0	27.4	35.0	39.7	40.1	41.1
Correlation coefficient (r)			.57*	.61*	.63**	.63**	.70**	.61**	.63**	.24	.19	.09	.20	.25	.24	.21

[1] L = Low yield, M = Medium yield, H = High yield.
* = Significant @ 5%.
** = Significant @ 1%.

most of them will germinate after a rain of ½ to 1 inch in the fall (Bentley and Talbot, 1951).

The yields were classed into three groups by a method similar to that used by Caprio (1966). The groups were: low yields, 800 to 1700 pounds; medium yields, 1800 to 2200 pounds; and high yields, 2600 to 3500 pounds. Yields from 6, 5, and 5 years were in the respective groups.

The time of the first precipitation in the fall sufficient to initiate germination was a prime factor in seasonal yield. Generally, if rain started in September, yield was high; but if it started in November, yield was low. Part of this response to early rainfall was the result of the higher temperatures in September and October than in November. The plants naturally grew at a more rapid rate than if germination had started when temperatures were considerably lower. With the high yield group, the rainfall 4 of the 5 years was above average in September and October, and by November 21 had exceeded 8 inches. In the exceptional year, 1966–67, the yield was 2600 pounds per acre, even though September–October precipitation was low. However, by November 20, rainfall was about 8 inches. The high yield in 1966–67 resulted primarily from higher than normal temperatures in December, which caused the growing season to be extended later than usual. In the low and medium yield years, total precipitation by November 20 was always less than 8 inches.

In relating yield to rainfall, especially in late summer or early fall, the effectiveness of the rain, insofar as plant growth is concerned, must be considered. Early precipitation is often insufficient to initiate germination; or, if germination is started, rainfall is not frequent enough, or heavy enough, to sustain growth. In the 1954 season, for example, 0.26 inches of rain was measured on August 30, but no additional rainfall occurred until October 10. The early rain came before germination had taken place, but the amount of moisture was not sufficient to initiate germination.

Total yearly precipitation was adjusted by subtracting the amount of ineffective rain. This value varied from 1.2 inches in the 1955 rainfall year to zero in 1958, 1960, 1961, 1965, and 1968.

The yield–rainfall relationship was most critical in November. At 5-day intervals, starting November 1, the coefficient of correlation values of forage yield to rainfall increased until the highest value ($r = .70$) was obtained on November 20 (Table 1). When the coefficient of correlations were calculated from December to May, the values were much lower, ranging from $r = .24$ to $.09$.

The regression equation for yield vs. precipitation as determined from data of November 20, is $\hat{Y} = 15.25 + 1.49X$, where $\hat{Y}$ = annual forage yield in pounds dry weight per acre and X = effective November precipitation.

Literature Cited

BENTLEY, J. R., AND M. W. TALBOT. 1951. Efficient use of annual plants on cattle ranges in the California foothills. U.S. Dep. Agr. Circ. 870. 52 p.

BLAISDELL, J. P. 1965. Growth and yield of sagebrush–grass vegetation in relation to precipitation and temperatures. Proc. 9th Int. Grassl. Congr., São Paulo, Brazil, 1:465–468.

CAPRIO, J. M. 1966. A statistical procedure for determining the association between weather and nonmeasurement biological data. Agr. Meteorol. 3:55–72.

DAHL, B. E. 1963. Soil moisture as a predictive index to forage yield for Sandhills range type. J. Range Manage. 16:128–132.

ELFORD, C. R., AND M. R. MCDONOUGH. 1963. Climate of Mendocino County. Univ. of Calif. Agr. Ext. Serv., 46 p.

GOWANS, K. D. 1958. Soil survey of the Hopland Field Station. Calif. Agr. Exp. Sta., 34 p.

ROGLER, G. A., AND H. J. HAAS. 1947. Range production as related to soil moisture and precipitation on the Northern Great Plains. Agron. J. 39:378–389.

SMOLIAK, S. 1956. Influence of climatic conditions on forage production of shortgrass rangeland. J. Range Manage. 9:89–91.

SNEVA, F. A., AND D. N. HYDER. 1962. Forecasting range herbage production in eastern Oregon. Sta. Bull. 588. Oregon State Univ. Agr. Exp. Sta., 11 p.

STITT, R. E. 1958. Factors affecting yield and quality of dryland grasses. Agron. J. 50:136–138.

TRUMBLE, H. C., AND E. A. CORNISH. 1936. The influence of rainfall on the yield of a natural pasture. J. Council Sci. & Industr. Res., Australia, 9:19–28.

TECHNICAL NOTES

Some Water Movement Patterns Over and Through Pinyon–Juniper Litter[1]

GERALD F. GIFFORD

Assistant Professor, Range Watershed Science, Range Science Department, Utah State University, Logan, Utah.

Highlight

Fluorescent dye patterns depicting water movement over and through pinyon–juniper litter accumulations varied somewhat according to canopy density of the trees. Where the canopy was closed, or nearly so, the dye was confined to the surface 1 inch of litter, with no lateral movement indicated. Where the tree canopy was broken or open, dye was found to a maximum of 6 inches beneath the litter and lateral downhill movement of at least 25 inches was indicated on the litter surface. Where dye had penetrated the litter, both a streaked and a uniform (even wetting front) pattern of water movement were observed.

Patterns of water movement in natural plant communities have been of interest for many years. Such patterns may exist due to unique spatial and temporal characteristics of rainfall, or because of characteristics of the flora which influence interception, transpiration, etc., and/or because of soil characteristics peculiar to a given site.

Importance of litter as a hydrologic factor in the pinyon–juniper (P–J) type has been noted by Scholl (1969). He found that resistance to wetting in the surface soils of a P–J watershed near Flagstaff, Arizona, increased from completely wettable in open areas to highly nonwettable in the litter under the juniper canopy. Similar findings have occurred in other vegetation types. Apparently organic unknowns which accumulate from litter decomposition or fungal activity cause the wettability problems.

The purpose of this study was to study patterns of water movement over and through pinyon–juniper leaf litter.

Methods

Water movement was traced on a pinyon–juniper (*Pinus monophylla, P. edulis–Juniperus osteosperma*) site in Southeastern Utah (45 miles west of Blanding, Utah) through use of two water soluble fluorescent dyes, Pyranine[2] and Kiton Yellow.[3] Pyranine will fluoresce in damp soil and Kiton Yellow fluoresces in the dry state.

During mid-June of 1969, 27 bands of dye powder (1 part Kiton Yellow to 1 part Pyranine) about 3 inches wide were put on the litter covered interspace between suitable pinyon and juniper trees (Fig. 1). The dyes were applied from a salt shaker at a rate of about 200 g/m^2, as recommended by Reynolds (1966). The dye transects varied from 48 to 170 inches in length and each ran from the base of one tree to the base of a nearby adjacent one. Maximum depth of litter was approximately 2.5 inches, with an average of about 1.5 inches.

In early September trenches were excavated along 20 randomly selected bands to study vertical dye penetration patterns. The remaining 7 bands were used to study water movement patterns over the litter surface. All measurements were made at night using a battery powered UVL-21 ultra-violet lamp.

Results

Penetration of dye into the litter was variable and type of pattern appeared related to tree canopy density. Where canopies were closed, or nearly so, the dye was confined to the surface 1 inch of litter, with no lateral movement indicated. Since total rainfall during the study period measured near normal (3.80 inches compared with probable normal range of 1.9 to 5.7 inches), throughfall and foliage drip are probably minimal under the closed canopies except in the case of large storms.

Where canopies were somewhat broken, dye patterns indicated rather nonhomogeneous vertical water movement, as shown in Figure 2. Similar irregular drainage patterns in wood-

---

[1] This study was in cooperation with the Bureau of Land Management, Contract 14-11-0008-2837. Their support is gratefully acknowledged. Journal Paper No. 972, Utah Agricultural Experiment Station, Logan, Utah. Received November 8, 1969; accepted for publication February 21, 1970.

[2] Verona Dyestuffs, Springfield Road, P.O. Box 385, Union, New Jersey.

[3] Keystone Ingham Corp., 8726 Cleta Street, Downey, California.

FIG. 1. Litter accumulation beneath two adjacent juniper trees. A band of dye powder would run from the base of one tree to the base of the other.

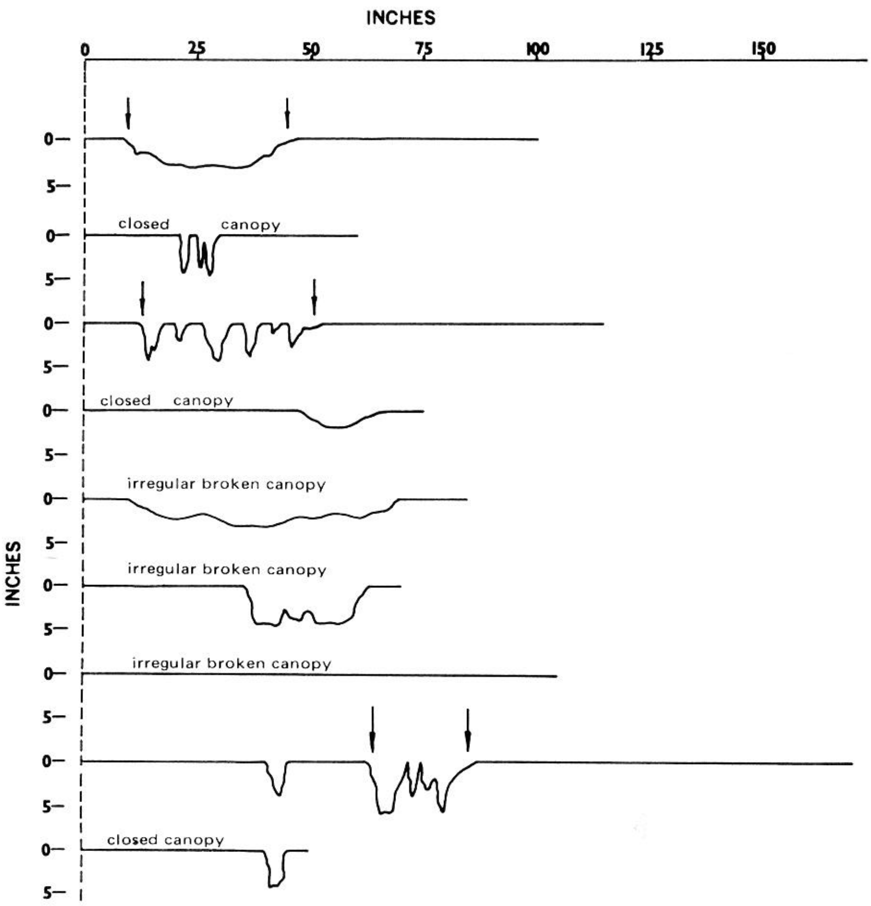


FIG. 2. Examples of some vertical dye penetration patterns through pinyon–juniper litter. Arrows indicate that portion of dye band over which the canopy was open.

land environments have been shown by Voigt (1960), Rutter (1964), and Reynolds (1966). Little or no dye movement was indicated next to either pinyon or juniper tree trunks, indicating that perhaps stemflow is rather insignificant in this type. Maximum depth of dye penetration beneath the litter surface along any excavated transect was 6 inches.

Some lateral flow over the litter surface also occurred where canopies were broken or open. Maximum indicated distance of overland flow was 25 inches, with vertical penetration into the litter of 1 inch or less. There were no indications of lateral flow within the litter cover. The overland flow may result when litter accumulations become dry and unwettable.

Conclusions

The influence of litter on hydrologic behavior of natural plant communities is not well defined. This study has shown that patterns of water movement upon and through pinyon–juniper litter are variable and are somewhat related to tree canopy density. Where the canopy is open, water may move uniformly through the litter or along pathways which result in a streaked dye pattern. Where water cannot penetrate the litter, then overland flow may occur for at least short distances.

Literature Cited

REYNOLDS, E. R. C. 1966. The percolation of rainwater through soil demonstrated by fluorescent dyes. J. Soil Sci. 17:127–132.

RUTTER, A. J. 1964. Studies in the water relations of *Pinus sylvestris* in plantation conditions. II. The annual cycle of soil moisture change and derived estimates of evaporation. J. Appl. Ecol. 1:29–44.

SCHOLL, D. G. 1969. Soil wettability in Utah juniper stands. Paper presented at A.A.A.S. meeting, Pullman, Washington, August 18–22.

VOIGT, G. K. 1960. Distribution of rainfall under forest stands. Forest Sci. 9:2–10.

Radioisotope Uptake by Selected Range Forage and Weed Species[1]

RICHARD E. ECKERT, JR., AND CLIFTON R. BLINCOE

Range Scientist, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, University of Nevada, Reno, Nevada and Professor, Department of Biochemistry and Pest Control, University of Nevada, Reno.

Highlight

Two wheatgrasses, one annual grass, and one annual forb were used to evaluate the uptake of fourteen gamma-emitting isotopes from an important range soil. Uptake of copper, molybdenum, and selenium ranged from moderate to very good from all soil horizons. Uptake of iodine and chromium was poor from the surface and lower soil horizons, respectively, but moderate to very good from other horizons. Other desirable characteristics of these isotopes for root-tracing studies are half-lives of from 12.8 hours to 128 days, and energy differences which permit detection of each isotope in the presence of others.

The growth and survival of perennial grass seedlings on rangeland are closely related to the depth, spread, and volume of root systems of competing species. The rooting characteristics of plants can be traced by injection of a radioisotope into the root zone and measurement of activity in the aerial portion of the plant. Radiophosphorus has been the most commonly used tracer isotope in plant research. Recently, more emphasis has been placed on other isotopes. Siaz del Rio et al. (1961) used ^{86}Rb to find the active root region of coffee trees. Price (1965) described a field method for use of ^{131}I to study root systems in shrub–steppe vegetation. In 1966, Cohen and Tadmore investigated the uptake of ^{32}P, ^{137}Cs, ^{60}Co, ^{22}Na, ^{85}Sr, and ^{90}Sr. These authors also evaluated a two layered injection system in which two isotopes were placed at different depths in a soil column. The appearance of isotope activity in leaf tissue indicated that roots had elongated to the depth of injection.

A prerequisite for use of any tracer material or placement system is a determination of isotope uptake by the species and in the medium to be used. In our range reseeding work (Eckert and Evans, 1967; and Evans et al., 1967), species of primary importance are the introduced perennial grasses, Nordan crested wheatgrass (*Agropyron desertorum*); and Amur intermediate wheatgrass (*A. intermedium*); the weedy annual grass, downy brome (*Bromus tectorum*); and weedy broadleaf-annual, tumble mustard (*Sisymbrium altissimum*).

The objectives of this study were to evaluate the uptake of a group of gamma-emitting isotopes from an important range soil by range plants, and to estimate their value for root-tracing studies.

Methods and Materials

Fourteen gamma-emitting isotopes were evaluated: Barium-Lanthanum (^{140}BaLa), Cesium (^{137}Cs), Cobalt (^{60}Co), Chromium (^{51}Cr), Copper (^{64}Cu), Iron (^{59}Fe), Iodine (^{131}I), Potassium (^{42}K), Molybdenum (^{99}Mo), Rubidium (^{86}Rb), Ruthenium-Rhodium (^{106}RuRh), Selenium (^{75}Se), Zinc (^{65}Zn), and Zirconium (^{95}Zr). Half-life and gamma-ray energy characteristics are given by Crouthamel (1960).

A soil classified as a member of a coarse loamy, mixed, mesic family of Durustollic Camborthids was the medium. Uptake of all isotopes was evaluated in the A_{12} horizon (5–10 cm), pH 6.8. More promising isotopes were also evaluated in the B_2 (20–35 cm), pH 7.0; B_3 (35–53 cm), pH 7.2; and IICI (53–71 cm), pH 7.8 horizons. Soil was screened and placed in 0.9 liter containers.

Five plants of intermediate wheatgrass, crested wheatgrass, downy brome, or tumble mustard were established in each container. When plants were about 6 weeks old, the isotope was injected with a spinal tap needle to a depth of 7.6 cm in the center of the container. Each isotope was injected at a rate of 10 μCi in 0.1 ml of water. At this rate, no isotope was toxic. Most isotopes were evaluated alone and with a suitable carrier.

Plants used to evaluate uptake of short half-life isotopes were sampled about 6 to 8 hours after injection and on 2 consecutive days after injection. Plants with longer half-life isotopes were sampled on 3 consecutive days after injection. A 1-g fresh-weight sample consisted of 1 or 2 culms from each grass plant, or 2.5 to 5.0 cm of growth from each mustard plant. Samples were placed in plastic vials, and radioactivity was determined with a multichannel gamma-ray spectrometer. A 10 by 20 cm NaI crystal was used. The resolution of the gamma-ray spectrometer, as the full-width at half-maximum, was 0.060 MeV for the 0.662 MeV gamma-ray of ^{137}Cs. This corresponds to 17 channels. As a measure of radioactivity, the three peak channels in any one gamma-ray peak were summed and divided by the counting time. The background count rate of the same channels was subtracted. The uptake of each isotope was converted to the following empirical rate scale: very good uptake—more than 1000 counts per minute; good—100 to 1000 cpm; moderate—50 to 100 cpm; poor—10 to 50 cpm; and very poor—0 to 10 cpm. This scale reflects the relative radioactivity of isotope in shoot tissue. Since samples were taken frequently, the speed with which activity appeared in the shoot after injection could be estimated.

Results and Discussion

An evaluation of all isotopes in soil from the A_{12} horizon showed poor or no uptake of Co, Fe, K, Rb, Zn, or Zr by the grasses and forb used. Cohen and Tadmore (1966) attributed poor uptake of Co to adsorption in a loess soil. The uptake of Zn and Zr, and Co, K, and Rb was not increased by addition of 1 mg and 10 mg of carrier, respectively. Uptake of Fe was not increased by additions of 1, 10, 100, or 1000 mg of carrier. Fe and Zn are bound tightly to the soil colloids and they, as well as Co and Zr, have low solubility in phosphate solution at the pH of the soil used. Macro quantities of K occur in soil and the amount of radioisotope used was probably insufficient to adequately label both soil and plant potassium. This group of isotopes does not appear useful for tracer studies in soil, however, they may be useful in sand or nutrient culture where adsorption would not occur and where pH could be adjusted. The long half-life of Co (5.27 years) makes this isotope undesirable for field studies due to health–physics problems.

---

[1] Contribution from the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture and the Nevada Agricultural Experiment Station, University of Nevada, Reno, Nevada, Journal Series No. 121. Received August 27, 1969; accepted for publication January 8, 1970.

Table 1. Relative uptake of five isotopes by four species grown on soil from four horizons (depth in cm). The rate scale was based upon activity counts in leaf and stem tissue.[1]

Isotope	Intermediate wheatgrass–crested wheatgrass				Downy brome				Tumble mustard			
	A_{12} (5–10)	B_2 (20–35)	B_3 (35–53)	IICI (53–71)	A_{12} (5–10)	B_2 (20–35)	B_3 (35–53)	IICI (53–71)	A_{12} (5–10)	B_2 (20–35)	B_3 (35–53)	IICI (53–71)
Cr + 10[2]	G	VG	P	P	G	M	P	P	G	VG	M	G
Cu + 10	G	G	VG	VG	VG	G	G	VG	G	G	G	G
I	P	VG	VG	VG	G	VG	VG	VG	G	G	M	G
Mo + 10	G	G	VG	VG	M	VG	VG	VG	G	VG	VG	VG
Se + 10	G	VG	G	G	VG	G	G	G	G	M	G	G

[1] Rate scale: VG = very good uptake, more than 1000 counts/minute; G = good uptake, 100–1000 cpm; M = moderate uptake, 50–100 cpm; P = poor uptake, 10–50 cpm.
[2] 10 mg of suitable carrier injected with isotope.

The uptake of BaLa, Cs, and RuRh by grass species was generally poor; uptake by mustard was generally moderate to good. The total uptake and speed of uptake of these isotopes possibly could be improved by the use of carriers. For example, plant tissue grown in soil treated with Cs without carrier had a very poor activity rating and activity was not detected for 8 days after treatment. The average activity of plant tissue grown in soil treated with Cs plus 10 mg of carrier was rated moderate, and activity was detected 3 days after injection. The long half-life of Cs (30.0 years) would limit the use of this isotope for field studies. However, ^{134}Cs with a 2.0 year half-life could be used.

The uptake of Cr, Cu, I, Mo, and Se from soil of the A_{12} horizon ranged from poor to very good (Table 1). Data for intermediate and crested wheatgrass were combined since uptake was similar. Isotopes with activity rating of moderate, good, or very good are well suited as tracers for use with the species and soil evaluated. The use of I is questionable. All three grass species had less uptake of this isotope from the A_{12} horizon than from other horizons. The retention of I may be due to a reaction with organic matter (Raja and Babcock, 1961 and Price, 1965). This problem may be overcome by use of a higher, but non-toxic, level of I; by use of a carrier; or by use in horizons with low organic matter. Mustard plants grown in the A_{12} soil did not show a depression in I activity.

Uptake of Cr and Se was enhanced by injection of 10 mg of the metal as chromic acid or sodium selenate, respectively, as carrier. For example, Se injected alone did not appear in intermediate wheatgrass samples until 2 days after placement; and the average 3-day activity rating was very poor. When injected with carrier, Se was detected in intermediate wheatgrass samples the day following placement, and the average 3-day activity rating was good. The same trend was found when Cr was injected with and without carrier. The uptake of Cu and Mo was not enhanced by use of carrier.

Isotopes of Cu, I, Mo, and Se had moderate to very good uptake from subsoil horizons (Table 1) and are well suited as tracers for the species and soil used. The poor uptake of Cr by the grass species from soil of the B_3 and IICI horizons would limit its use in soil of this type. In some manner the Cr ion injected became unavailable to the grass species used. This response may be due to a decrease in the solubility of this ion with increased pH. Uptake of Cr by mustard showed a similar trend, however, activity was rated moderate. Increased isotope dose or increase in carrier may correct this problem. The increased uptake of Mo by all species from the subsoil horizons may be due to increased solubility of Mo at higher pH.

As a group, Cr, Cu, I, Mo, and Se give the researcher a series of tracers with markedly different half-lives and gamma-ray energies. Because of energy differences, these isotopes can be determined individually in the presence of each other. The very short half-life of Cu makes it especially valuable for short-term studies or where exclusion and disposal are problems. The longer half-life of Se suggests its possible use where long term measurements are necessary. For studies that require a longer half-life than 12.8 hours or shorter half-life than 128 days, Cr, I, and Mo could be used. The rapid uptake of Mo is evidenced by activity counts in excess of 10,000 counts per minute in leaf tissue 6 to 8 hours after injection. Since these isotopes are gamma emitters, no special sample preparation is needed prior to counting.

The solubility of isotopes in water and subsequent leaching from zone of placement is important in root-tracer technique. Schultz (1965) points out that a consideration of inorganic soil chemistry together with all other possible influences is necessary to predict movement of ions through soil.

Based upon the work of Jackson (1958), Bear (1964), Menzel (1965), and Schultz (1965), the mobility of chromium, copper, iodine, molybdenum, and selenium can be estimated. Of this group, chromium is the least soluble with the degree of solubility dependent upon type of clay mineral and soil pH. When soluble copper is added to the soil it tends to become less soluble due to formation of hydroxides or adsorption on soil colloids. In these forms copper is less soluble than most of the alkaline earth elements. Iodine is somewhat less strongly adsorbed than copper and therefore is more mobile in the soil solution. Molybdenum undergoes fixation in the molybdate form similar to phosphate, however, solubility is strongly influenced by soil pH. In general, molybdenum is more mobile than chromium, copper, or iodine. Selenium oxidizes to selenate and has leaching characteristics similar to sulfur. Selenium appears to be the most mobile of the elements discussed.

In spite of the apparent solubility and mobility of some isotopes in the soil, placement and sampling techniques could be devised to minimize leaching. For example, isotopes could be injected when soil moisture content was near or below field capacity. At this moisture level, movement of isotopes in soil solution would be restricted because of unsaturated flow conditions and a marked decrease in water movement through soil. Rapid uptake of some isotopes suggests that an adequate activity measurement could be obtained shortly after placement and thereby minimize leaching problems.

Conclusions

Our evaluation of the uptake of fourteen isotopes showed Cu, Cr, I, Mo, and Se were, with few exceptions, well suited for use as tracers with the species and soil used. These isotopes can be determined in the presence of each other by gamma-ray spectrometry. In our opinion, these results can be extrapolated for use with other species of perennial and annual grasses and annual forbs. These isotopes can also be used in soils with low organic matter, near neutral reaction, and loamy texture. Further study is needed to evaluate: (1) isotope uptake by perennial forb and shrub species; (2) isotope uptake from soils with acid or alkaline reaction, high organic matter, and very light or heavy texture; and (3) leaching of isotopes from zone of placement.

Literature Cited

Bear, Firman E. (Ed.). 1964. Chemistry of the soil. (2nd Ed.). Reinhold Publishing Corporation, New York. 515 p.

Cohen, Yehezkel, and Naphthali H. Tadmore. 1966. Root tracing by two-layer radioisotope application. Int. J. of Applied Radiation and Isotopes 17:573–581.

Crouthamel, C. E. 1960. Applied gamma-ray spectrometry. Pergamon Press Ltd., New York. 443 p.

Eckert, Richard E., Jr., and Raymond A. Evans. 1967. A chemical-fallow technique for control of downy brome and establishment of perennial grasses on rangelands. J. Range Manage. 20:35–41.

Evans, Raymond A., Richard E. Eckert, Jr., and Burgess L. Kay. 1967. Wheatgrass establishment with paraquat and tillage on downy brome ranges. Weeds 15:50–55.

Jackson, M. L. 1958. Soil chemical analyses. Prentice-Hall, Inc., Englewood Cliffs, N. J. 498 p.

Menzel, R. G. 1965. Soil-plant relationships of radioactive elements. Health Physics 11:1325–1332.

Price, Keith R. 1965. A field method for studying root systems. Health Physics 11:1521–1525.

Raja, Manzoor E., and K. L. Babcock. 1961. On the soil chemistry of radio-iodine. Soil Sci. 91:1–5.

Schultz, R. K. 1965. Soil chemistry of radionuclides. Health Physics 11: 1317–1324.

Siaz del Rio, J. F., C. E. Fernandez, and O. Bellavita. 1961. Distribution of absorbing capacity of coffee roots determined by radioactive tracers. Proc. Amer. Soc. Hort. Sci. 77:240–244.

Large Seeds Produce More, Better Alkali Sacaton Plants[1]

O. D. KNIPE

Associate Plant Ecologist, Rocky Mountain Forest and Range Experiment Station, Albuquerque, New Mexico.

Highlight

Larger seeds of alkali sacaton germinated better and faster than the smaller sizes. Seedlings from larger seeds emerged from deeper depths and had a higher growth rate.

During the course of previous work I observed considerable variation in seed size of alkali sacaton (*Sporobolus airoides* Torr.). In addition, it appeared that the larger seeds had a higher percentage germination and that they germinated more rapidly than the smaller seeds.

The purposes of this study were to determine seed size classes and the relation of seed size to (1) time required for germination, (2) total germination, and (3) emergence in alkali sacaton.

The larger and/or heavier seeds of grasses have generally been found to produce seedlings of greater vigor than seedlings produced by the smaller seeds. Several workers have found that the heavier and/or larger seeds within certain grass species emerge better and from deeper depths than the smaller and/or lighter seeds (Hunt, 1954; Kittock and Patterson, 1962; Milton, 1935; and Rogler, 1954). A number of workers have reported that larger seeds result in better stands and more vigorous seedlings (Harkness, 1965; Kneebone, 1956; Kneebone and Cremer, 1955; Rogler, 1954; and Tossell, 1960).

Procedures

Six seed size classes were delineated by passing thoroughly cleaned seeds (caryopses free of lemma and palea) through screens with 28 × 28, 30 × 30, 32 × 32, 34 × 34, and 36 × 36 openings per square inch. Seeds held by (that would not pass through) the 28 × 28 screen were designated size 1, those held by the 30 × 30 screen as size 2, etc. Size 6 seeds were those which passed through the smallest (36 × 36) screen. The percentage (weight basis) of seeds in each size class, and the number of seeds per pound, was determined for each of six seed lots.

To determine the effect of seed size on the rate of germination of alkali sacaton, a 30-day germination test was run on four replications of 100 seeds of each of the six seed sizes from the 1966 seed lot. The seeds were germinated on doubled layers of standard blue germination paper in 4-inch petri dishes in a controlled-environment

[1] Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Dept. of Agriculture, with central headquarters maintained at Fort Collins in cooperation with Colorado State University; author is located at Albuquerque in cooperation with the University of New Mexico. Research reported here was conducted in cooperation with the Bureau of Land Management, U.S. Dept. of the Interior. Received October 15, 1969; accepted for publication January 27, 1970.

Table 1. Percentage of seeds (weight basis) per size class and number of seeds per pound in six lots of alkali sacaton.

Size class	Seed lot[1]						
	RP1964	RP1965	RP1966	RP1967	PMNM-184	PMNM-C14	Avg, all lots
1	47	70	42	88	44	42	56
2	19	18	22	8	18	36	20
3	12	7	20	2	22	13	12
4	10	3	7	1	8	7	6
5	5	1	5	1	5	2	3
6	7	1	3	1	3	1	3
Seeds/lb.	2,000,000	1,435,000	1,550,000	1,040,000	2,240,000	1,540,000	1,634,000

[1] Seed lots RP were collected by the author in the Rio Puerco watershed about 60 miles northwest of Albuquerque, New Mexico during October of the indicated year. The other two lots were obtained from the New Mexico Plant Materials Center, Los Lunas, New Mexico.

germination chamber. The chamber was programmed for 8 hours light daily at 90 F and 16 hours darkness at 70 F; relative humidity ranged from 95 to 98 percent. Previous studies have shown that these conditions are adequate for germination of alkali sacaton (Knipe, 1967). A seed was considered as germinated when both radicle and plumule had broken through the seed coat.

The effect of seed size on emergence from different depths of planting was studied by planting seeds of sizes 1 and 3 in a greenhouse in 2-quart pots in sterile sandy loam soil at depths of ½, 1, and 1¾ inches. The pots were subirrigated to saturation at the start of the study; additional waterings were not necessary. This study consisted of 6 replications of 15 seeds per pot. The temperature of the greenhouse ranged from 80 to 90 F, and the relative humidity ranged from 60 to 70 percent. Percent emergence was determined for the 14th day after planting.

To determine the effect of seed size on root and shoot growth, a separate set of pots, identical to those described above but with 8 replications, were seeded with sizes 1 and 3 at a depth of ¼ inch. The seedlings which emerged in these pots were excavated—those in 4 pots 7 days after planting, and those in the other 4 pots 14 days after planting—and the lengths of their roots and shoots determined.

Results of each of the studies were analyzed as a randomized complete block, those from the latter study as unequal subsample numbers because the number of seedlings per pot was not constant. The germination and emergence percentages were transformed to arc sin of square root of percentages prior to analysis.

Results and Discussion

Separating seeds of several lots of alkali sacaton into six size classes revealed a considerable variation in the percentage of seeds per size class among lots (Table 1); the number of seeds per pound also varied among lots, ranging from more than one to more than two million per pound. Over half of the seeds were in size class 1, the largest seeds.

Three days after the start of the germination test the smallest seeds (size 6) had the lowest percentage germination; each successively larger size was significantly better.[2] This relationship continued with one minor exception for all sizes for the duration of the 30-day period (Table 2). The germination percentage of size 1 approached maximum on the third day, whereas the smaller seeds did not approach maximum germination until the seventh day. The larger seeds of alkali sacaton were not only more viable but they also germinated faster.

[2] All significant differences specified in this paper were at the .05 level.

Seedling emergence in pots with size 1 seed was significantly higher than in pots with size 3 seed at all depths of seeding. Seed size 1 had a higher emergence (%) from the 1-inch planting depth than was obtained with size 3 seeds from the ½-inch depth:

Inches depth	Size 1	Size 3
½	89a[3]	50
1	83a	15b
1¾	22b	0

The growth rate (cm) of seedlings from the large seeds greatly exceeded that of the small seeds, especially with respect to root growth:

Days	Root length		Shoot length	
	Size 1	Size 3	Size 1	Size 3
7	2.3[4]	0.9	2.1	1.4
14	4.5	2.2	2.2	1.8

Conclusions

The results indicate that the larger seeds, by virtue of more rapid germination and development, produce seedlings better adapted to establishment in harsh areas. It is possible that establishment of plants from the larger seeds contributes greatly to natural regeneration of alkali sacaton under natural conditions in arid and semiarid regions. The success of field seedings would probably be enhanced if operations were restricted to the use of large seeds.

[3] Any two values followed by the same letter are not significantly different (.05 level, Tukey procedure).

[4] All values between seed size 1 and 3 at a given age are significantly different (.05 level, Tukey procedure).

Table 2. Germination (%) of six sizes of alkali sacaton seed (lot RP1966) after 2, 3, 7, 14, 21, and 30 days.

Seed size	Days after start of test					
	2	3	7	14	21	30
1	6	80	81	83	83	83
2	4a[1]	58	67	68	68	68
3	2a	47	57b	59b	59b	59b
4	3a	42	57b	58b	59b	59b
5	1a	32	47	47	48	48
6	2a	17	25	26	26	26

[1] Any two values in a column not followed by the same letter are significantly different (Tukey procedure .05 level).

Literature Cited

HARKNESS, R. O. 1965. The effect of seed size on early growth of diploid and tetraploid Italian ryegrass. J. Brit. Grassland Soc. 20:190–193.

HUNT, I. V. 1954. Seed establishment in the west of Scotland. J. Brit. Grassland Soc. 9:85–98.

KITTOCK, D. L., AND J. K. PATTERSON. 1962. Seed size effects on performance of dryland grasses. Agron. J. 54:277–278.

KNEEBONE, W. R. 1956. Breeding for seedling vigor in sand bluestem (*Andropogon hallii* Hack.) and other native grasses. Agron. J. 48:37–40.

KNEEBONE, W. R., AND C. L. CREMER. 1955. The relationship of seed size to seedling vigor in some native grasses. Agron. J. 47:472–477.

KNIPE, O. D. 1967. Influence of temperature on the germination of some range grasses. J. Range Manage. 20:298–299.

MILTON, W. E. J. 1935. The soil establishment of pedigree and commercial strains of certain grasses. Welsh J. Agr. 11:171–181.

ROGLER, G. A. 1954. Seed size and seedling vigor in crested wheatgrass. Agron. J. 46:216–220.

TOSSELL, W. E. 1960. Early seedling vigor and seed weight in relation to breeding in smooth bromegrass (*Bromus inermis* Leyss.). Can. J. Plant Sci. 49:268–280.

Vegetative Reproduction of Fourwing Saltbush in New Mexico[1]

ROBERT G. WOODMANSEE[2] AND LOREN D. POTTER

Department of Biology, The University of New Mexico, Albuquerque, New Mexico.

Highlight

Root sprouting was found to be an important method of reproduction in some stands of fourwing saltbush in New Mexico.

The importance of vegetative reproduction by root sprouts in the palatable and nutritious Southwestern shrub, fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.), has not been reported previously in the literature. Hervey (1955) found plants in Colorado that had sprouted from adventitious buds on root crowns or from the underground portion of the stem, but he made no mention of other forms of vegetative reproduction. Nord, Christensen, and Plummer (1969) reported vegetative reproduction in *A. gardneri* and *A. nuttallii.*

[1] This research was supported through a cooperative agreement with the Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Fort Collins, Colorado, and was part of a master's degree thesis at the University of New Mexico. Received January 29, 1970; accepted for publication March 2, 1970.

[2] Present address: College of Forestry and Natural Resources, Department of Range Science, Colorado State University, Fort Collins.

FIG. 1. Mature, 3 ft tall, fourwing saltbush (upper right) with attached, 2 ft tall, seed-bearing sprout (lower left).

In the summers of 1967 and 1968, we found root suckers from the extensive lateral roots just below the soil surface in three stands of fourwing saltbush in central New Mexico. In these stands the sprouts appeared to be an important means of reproduction.

At one site (SE ¼ Sec. 6, T.15N., R.17W.) near Fort Wingate, New Mexico, roots of 100 young-appearing plants of fourwing saltbush were examined to determine the nature of their origin in the alluvial soil of heavy clay loam to clay. Seventy-seven percent of the plants were determined to be of root sucker origin. The average distance of the young sprout from the parent plant was about 4 ft, and the greatest distance was 8 ft (Fig. 1).

Another site (SW ¼ Sec. 12, T.12N., R.4E.) was on the water diversion terraces of the steep west-facing slope in the Bernalillo Watershed near Bernalillo, New Mexico. The species at this site was introduced in the late 1950's as part of the revegetation efforts of the watershed project. Of 50 young plants examined, 96% were found to be of root sucker origin. The soil on this site was gravelly sandy loam. Again, the average distance of root sprouts from the parent plant was 4 ft and the maximum was 8 ft.

Root sprouts of fourwing saltbush were also located on a steep, rocky, limestone, northwest-facing slope in Lower Las Huertas Canyon, south of Placitas, New Mexico (SW ¼ Sec. 15, T.12N., R.5E.). Young plants of different origins were not counted, but it was apparent that vegetative reproduction was common.

Vegetative reproduction in fourwing saltbush appears to occur infrequently, but in areas such as Fort Wingate, reproduction by root sprouts as far as 8 ft from the parent bush is important. This method of reproduction is probably much more efficient and dependable than sexual reproduction. More investigations should be made to determine if root sprouting is due to genetic variation or edaphic conditions.

Literature Cited

HERVEY, DONALD F. 1955. Factors which influence the reseeding of certain browse species in Colorado. Dissertation. Texas A. & M., College Station.

NORD, E. C., D. R. CHRISTENSEN, AND A. P. PLUMMER. 1969. Atriplex species (or taxa) that spread by root sprouts, stem layers, and by seed. Ecology 50:324–326.

Seasonal Variation of Chlorophyll in Western Wheatgrass and Blue Grama[1]

FRANK RAUZI AND
ALBERT K. DOBRENZ[2]

Soil Scientist, U.S. Department of Agriculture and Assistant Professor of Crops, University of Wyoming, Laramie.

Highlight

Chlorophyll concentrations in western wheatgrass and blue grama were evaluated during the period June 29 through October 29, 1965, at the Archer Substation, Cheyenne, Wyoming. Chlorophyll a was more abundant than chlorophyll b in both the western wheatgrass and blue grama during the study period. Concentrations of chlorophyll a and b in the western wheatgrass was greater than in the blue grama. Chlorophyll a and b and total chlorophyll decreased with maturity of the plants.

The role of chlorophyll in providing energy for plant metabolism has long been established. However, there is a paucity of information on the seasonal variation of this biochemical constituent in native grasses.

The chlorophyll content of the cell is, perhaps, more closely associated with the photosynthetic performance than is any other factor; and wide variations in photosynthetic rate of leaves are to be expected, particularly under field conditions (Bonner and Galston, 1955).

Significant differences in percentage total chlorophyll was found in 55 clonal lines of Fairway crested wheatgrass (*Agropyron cristatum* (L.) Gaertn) by Johnson and Miller (1940). Bray (1960), working with six forests and thirteen native and managed herbaceous stands in central Minnesota, concluded that all the natural herbaceous stands had an approximately similar ratio of chlorophyll to dry weight of the above-ground parts. Bray also found a significant positive correlation between chlorophyll content and herbaceous stand height. Brougham's (1960) study suggests that the chlorophyll in a species with horizontally disposed or flagged leaves is more active or efficient in converting carbon dioxide than species with more erect leaves. A chlorophyll index for turf grass responses was determined by Madison and Anderson (1963). The chlorophyll index showed significant difference only from the fertilized treatments, and increased with an increase of N fertilizer.

During 1965, the seasonal trends of chlorophyll concentrations in western wheatgrass and blue grama were evaluated at the Archer Substation near Cheyenne, Wyoming.

Methods and Procedure

Entire plants of western wheatgrass (*Agropyron smithii*), a cool season grass, and blue grama (*Bouteloua gracilis*), a warm season grass, were clipped at ground level approximately every two weeks from June 29 through October 29 on a moderately grazed native pasture. Western wheatgrass produced no seed heads during the 1965 season, and remained green and in a vegetative stage throughout the collection period. Blue grama produced numerous seed heads that were included in the clipped plant material. Plant materials were air-dried and ground with a stainless steel Wiley Mill with 60-mesh openings. Extraction and spectrophotometer determinations of chlorophyll a and b were accomplished by Koski's (1950) technique.

Results and Discussion

Total concentration of chlorophyll and chlorophyll a and b in the western wheatgrass declined rapidly after the July 29 collection date (Fig. 1).

The total chlorophyll concentration of the western wheatgrass had a tendency to level off during the forepart of September, and it decreased again with a slight increase occurring between September 30 and October 13. The increase of chlorophyll concentration was perhaps a result of increased plant growth because of the ample moisture, clear skies, and warm daytime temperatures during the early fall.

The differences in chlorophyll a and b concentrations in western wheatgrass were quite pronounced between June 29 and July 29, after which the difference in chlorophyll a and b content decreased rapidly with maturity. On October 29 the difference between chlorophyll a and b concentration was negligible.

The chlorophyll concentration of blue grama decreased markedly between June 29 and July 14 (Fig. 1). The last rain in June (.24 inch) was on the 24th, and precipitation from June 29 to July 14 was only .14 inch (Table 1). Thus, little or no plant growth occurred between the first and second sampling dates. A decided increase in the chlorophyll concentration occurred between July 14 and

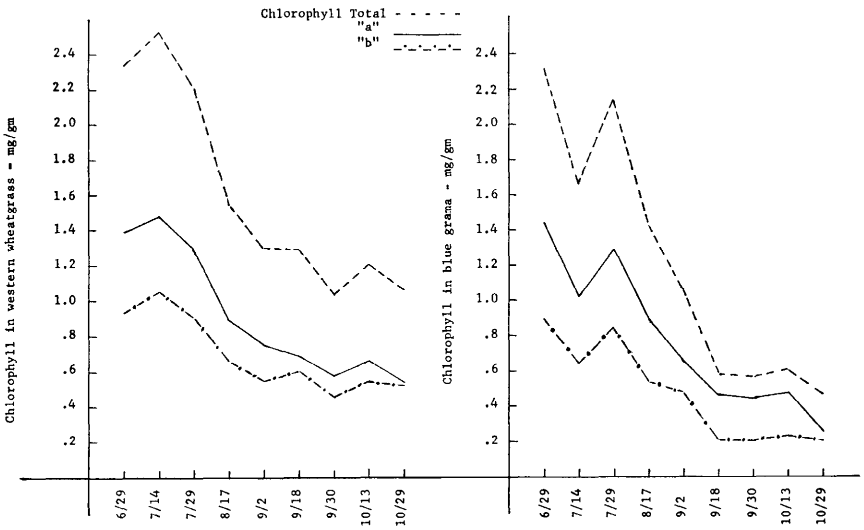


FIG. 1. Chlorophyll a and b, and total chlorophyll for western wheatgrass and blue grama. Archer Substation, Wyoming. 1965.

---

[1] Contribution from Northern Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, and the Wyoming Agricultural Experiment Station. Journal No. 394. Received August 15, 1969; accepted for publication January 31, 1970.

[2] Present address: University of Arizona, Tucson.

Table 1. Precipitation (inches) for the sampling dates during June, July, August, September, and October. Archer Substation, Wyoming. 1965.

Sampling date	Precipitation
6/29– 7/14	.14
7/14– 7/29	1.53
7/29– 8/17	.73
8/17– 9/ 2	.05
9/ 2– 9/18	.95
9/18– 9/30	1.06
9/30–10/13	.00
10/13–10/29	1.17

July 29 as a result of 1.53 inches precipitation and resultant plant growth.

Total chlorophyll and chlorophyll a and b concentrations in blue grama again declined sharply between July 29 and September 18, probably as a result of decreasing precipitation and an increase in plant maturity. Chlorophyll concentration in the blue grama increased slightly between September 18 and October 13. The small increase was associated with conditions more favorable for plant growth as a result of the precipitation received during September.

During the study period western wheatgrass plant material contained 25% more total chlorophyll than did the blue grama plant material. The greater amount of total chlorophyll concentration in the western wheatgrass may have resulted from the plants being under more soil-water stress than were the blue grama plants.

Table 2. Total chlorophyll (mg/gm) and percentage difference between western wheatgrass and blue grama. Archer Substation. 1965.

Date	Western wheatgrass	Blue[1] grama	Percentage[2] difference
6/29	2.33	2.34	0.0
7/14	2.53	1.66	34.4
7/29	2.21	2.14	3.2
8/17	1.55	1.44	7.1
9/ 2	1.30	1.05	19.2
9/18	1.29	.58	55.0
9/30	1.03	.56	45.6
10/13	1.20	.61	49.2
10/29	1.06	.47	55.7

[1] Plant material includes seed stalks and heads.

[2] Western wheatgrass used as the base for comparing percentage differences in total chlorophyll.

Total chlorophyll concentration (percentage basis) of western wheatgrass was greater than that of the blue grama at all sampling times, except the first when they were the same (Table 2). The difference in total chlorophyll concentration between the two species was smallest during the fifth sampling period, and the greatest during the seventh sampling time. After the fifth sampling date, the difference in total chlorophyll concentration between the two species increased markedly.

Chlorophyll a was more abundant than chlorophyll b in both grass species throughout the growing season. The ratio of chlorophyll a to b decreased with time in both species. Chlorophyll a and b concentration of western wheatgrass was greater than that of blue grama. The decrease in amount of chlorophyll became more pronounced with the advance of the season. Thus, the stage of maturity and the climatic conditions appeared to influence the chlorophyll concentration in blue grama and western wheatgrass plants.

Literature Cited

BONNER, JAMES, AND ARTHUR W. GALSTON. 1955. Principles of plant physiology. W. H. Freeman Company. 499 p.

BRAY, J. R. 1960. The chlorophyll content of some native and managed plant communities in central Minnesota. Can. J. Bot. 38:313–333.

BROUGHAM, R. W. 1960. The relationship between critical leaf area, total chlorophyll content and maximum growth rate of some pasture and crop plants. Ann. of Bot. N. S. 24:463–474.

JOHNSON, I. J., AND ELMER S. MILLER. 1940. Leaf pigment concentrations and its relation to yield in fairway crested wheatgrass and parkland bromegrass. J. Amer. Soc. Agron. 32:302–307.

KOSKI, VIOLET. 1950. Chlorophyll formation in seedlings at Zea Mays L. Art. Biochem. Biophys. 29:339–343.

MADISON, JOHN H., AND AAGE H. ANDERSON. 1963. A chlorophyll index to measure turfgrass response. Agron. J. 55:461–464.

MANAGEMENT NOTES

Planned Grazing for Montana Ranges[1]

NED W. JEFFERIES

Extension Range Management Specialist, Cooperative Extension Service, Montana State University, Bozeman.

Highlight

Grazing management alternatives for Montana ranches are discussed. Management is usually based on one of the following programs: seasonlong grazing, deferred rotation, rest rotation or seasonal grazing. The grazing program must then be adapted to the individual ranch or range unit.

[1] Received February 13, 1970; accepted for publication March 4, 1970.

There is no grazing system that is best under all conditions. The rancher must make a choice based on the knowledge of his range, livestock operation, and economic position. The system that he follows must then be tailored to fit his operation (Anderson, 1967a).

Specialized grazing systems, such as the deferred rotation or rest rotation, are designed to increase the quantity of desirable range vegetation. They are not designed to increase individual livestock gains. Increased grazing capacity and gains per acre will result from the production of a greater amount of forage and more efficient use of it. If the stocking rate was correct prior to initiating a specialized grazing system, a large increase in the gains of individual animals will probably not occur. However, over a period of years, the rancher will be able to increase his stocking rates and increase his livestock production per acre.

Seasonlong Grazing

Seasonlong grazing is the term used to designate grazing a single range unit throughout the entire growing season. Seasonlong grazing in Montana is least harmful to ranges dominated by low growing grasses capable of vegetative reproduction. Grasses such as blue grama (*Bouteloua gracilis*), buffalograss (*Buchloe dactyloides*), and Kentucky bluegrass (*Poa pratensis*) are quite resistant to total defoliation and can withstand repeated grazing. Bunchgrasses such as green needlegrass (*Stips viridula*), bluebunch wheatgrass (*Agropyron spicatum*), and rough fescue (*Festuca scabrella*) depend upon seeds for reproduction. They are more readily defoliated and are easily damaged unless rest periods are provided.

With proper rates of use, range condition can be maintained under seasonlong grazing. However, it is difficult to improve a range with this type of grazing management.

Some improvement in range condition may occur in response to the development of additional water facilities or through fencing to obtain better distribution of grazing livestock. Obtaining proper distribution of the grazing animals and determining a realistic stocking rate are the two hardest problems encountered in seasonlong grazing.

Advantages

1. Cattle have access to the entire range area throughout the growing season. They are allowed greater selectivity of forage during the early portion of the grazing season than under any other system.

2. Cattle, especially cows, tend to find a "home" for themselves. This reduces "fencewalking" and "fencecrawlers."

3. There is a minimum of livestock herding and movement involved.

4. The investment in fencing and labor is minimal.

5. Under similar range conditions, gains of individual animals are often greater than under the deferred rotation system.

Disadvantages

1. It is difficult to obtain adequate distribution of livestock to eliminate or reduce areas of overgrazing and undergrazing.

2. It is difficult to obtain the proper stocking rate and to retain flexibility in stocking to avoid overgrazing during dry years.

3. The preferred grasses are subjected to both early and repeated grazing which are especially detrimental. It is difficult to maintain key forage species under these conditions.

Deferred Rotation Grazing

Rotation grazing refers to a system in which livestock are periodically moved from pasture to pasture when proper or full use has been attained. Under deferred rotation grazing, each year the grazing on at least one pasture is deferred until the key species have produced seed. The order in which the pastures are grazed is changed yearly or every two years so no pasture receives use during the same period every year (Anderson, 1967b). A diagramatic scheme is shown in Figure 1.

	Spring	Summer	(Seed Maturity)	Fall
First Year	Unit A	Unit B	Unit C	Unit A
Second Year	Unit C	Unit A	Unit B	Unit C
Third Year	Unit B	Unit C	Unit A	Unit B

FIG. 1. Example of a deferred rotation grazing system with three grazing units.

A deferred rotation system may be established with two, three or more pastures. When deferment is alternated between two pastures, it can be called a switchback system. Another variation involves grazing all pastures throughout the grazing season except the pasture being deferred. A different pasture is deferred each year.

The period when grazing is most detrimental varies between the species of grasses, forbs, and shrubs. It is most important that pastures are not grazed at the same time each year. Systematically changing the time of grazing will tend to maintain all of the more desirable species.

Advantages

1. Concentrating livestock on a smaller area forces the livestock to utilize portions of the range that normally would receive little or no grazing.

2. The movement of livestock from pasture to pasture reduces the repeated grazing of preferred plant species. These plants are allowed to mature and build up high carbohydrate reserves on a portion of the range each year.

3. Livestock breeding efficiency may be increased due to the greater concentration of the breeding herd.

4. Forage production usually increases rapidly on low condition bunchgrass ranges. Ranges in high condition or ranges dominated by clubmoss or blue grama sods respond less rapidly.

Disadvantages

1. This system is more easily adapted to ranges not having large differences in vegetation or topography. Large differences in elevation present problems of range readiness for early grazing. Areas with several vegetation types are often more easily managed when fenced so that each type is in a separate unit.

2. To adapt a range for deferred rotation grazing usually requires additional fencing and water development. Springs, seeps, and ponds which furnish adequate water for a small number of livestock throughout the grazing season are often inadequate for large livestock numbers over a short period of time.

3. Livestock must be handled more frequently than under seasonlong grazing. This handling can often be reduced by allowing a period for the natural drifting of cattle into the next pasture to be grazed. The movement of livestock should be considered during planning to eliminate long or difficult drives between pastures.

	Graze early	Rested or deferred	Graze late	Rest
First Year	Unit A	Unit D	Unit C	Unit B
Second Year	Unit B	Unit A	Unit D	Unit C
Third Year	Unit C	Unit B	Unit A	Unit D
Fourth Year	Unit D	Unit C	Unit B	Unit A

FIG. 2. Example of a rest rotation grazing system with four grazing units.

4. Extreme care must be used to avoid overgrazing during the earliest grazing period. Usually, the grasses are in a rapid growth stage during this period and are easily damaged. The stocking rate of a pasture during the early part of the growing season is not as great as it would be later.

Rest Rotation Grazing

Rest rotation grazing might be termed the "crash program" management system. Under this system, the range area is divided into four or more grazing units of approximately equal grazing capacity (Fig. 2). With a four pasture system, two or three of the pastures are grazed each year. One unit is grazed early, and another unit is grazed after seedset. A third unit is either grazed late in the growing season or rested to build up the vigor of the key forage species. At least one pasture receives complete rest from grazing. The grazing sequence is rotated every year so that each pasture receives over a four year period, one year of early grazing, one or two years of late grazing, and at least one year of complete rest.

The theory behind this system can best be explained by following a pasture through a four year cycle (Hormay and Talbot, 1961). The first year, the pasture would be grazed heavily during the early portion of the year to obtain full forage use on the area. It would then be protected during the latter part of the season. The second year, the pasture would receive no use or late use allowing the plants to regain vigor. The third year, the pasture would be grazed during the latter part of the season after seeds have been produced by the key species. This grazing would aid in distributing and covering seeds. The pasture would be rested the fourth year to allow seedling establishment.

Advantages

1. Bunchgrass ranges in poor to fair condition respond rapidly to this type of management. These ranges are dependent mostly on seeds for regeneration.

Seed production is of less importance to the recovery of plains ranges and is much less reliable. Range improvement in these grasslands is a result of a) vegetative reproduction of rhizomatous species such as western and thickspike wheatgrasses (*Agropyron smithii* and *A. dasystachum*); b) increased vigor and plant size of desirable bunchgrasses; c) reduced density of clubmoss and blue grama sods; and d) new seedlings of desirable grasses, forbs, and shrubs.

2. Other range improvement practices such as reseeding and weed or brush control can fit into this program quite easily.
3. Distribution of range use may be improved due to concentrating greater numbers of livestock on a small area for a short period of time. Selective grazing is reduced, at least to some extent (Ratliff, 1962).

Disadvantages

1. If the range has been stocked to obtain full use of the entire range unit prior to the initiation of this grazing system, the grazing intensity often employed under the rest rotation program can be detrimental.

If the entire range unit has not been utilized, but key portions have received heavy use, then only slightly heavier overall use of range plants will result due to the improved livestock distribution. The effect of this grazing is usually overcome by the years of rest or deferment.

2. This system is most easily applied to areas of similar vegetation and topography.

3. More fences and water developments are required with this system than under seasonlong grazing. Adequate watering facilities are especially critical when a rest rotation grazing system is used.

4. The heavier grazing intensity may initially result in lower individual gains on yearling cattle. This effect on the weight gains will diminish as the productivity of the pastures increases.

Seasonal Grazing

Many Montana ranchers must fit their livestock operations to ranges with dissimilar vegetation and large elevational differences. This is especially true of the foothills and mountain valley ranches utilizing mountain rangelands or cut-over timberlands. A specialized grazing system may be used on a portion of the range, but the livestock grazing must be scheduled to fit the seasonal availability of forage.

Advantages and Opportunities

1. Grazing can be scheduled when grasses are most palatable and nutritious, or to meet the requirements of the vegetation or livestock.

2. Individual pastures can be deferred, rested or lightly grazed to build up vigor and improve range condition.

3. Pastures seeded to introduced cool season grasses can be used to defer or delay grazing on native species. These pastures also fill the need of lactating animals for large quantities of early forage (Houston and Urick, 1967).

4. When possible, a deferred or rest rotation system should be incorporated in the grazing program.

Disadvantages

1. Unless the operator has an adequate knowledge of the range plants and their reactions to grazing, little improvement of the range will be attained.

2. On rougher range units, poor livestock distribution is often the cause of overgrazing, not excessive livestock numbers. Better distribution of livestock on these ranges can be attained by improving watering facilities, salting, riding,

etc. The intensive use of small pastures for short periods rather than large pastures will also result in better distribution of grazing.

Summary

No grazing system can override the effects of continuous overuse on the range. The maximum profit from a piece of rangeland involves a compromise between maximum livestock gains per acre and maximum gains on a per head basis. Maximum gain per acre is attained with heavy stocking of the range and maximum individual gains occur with light stocking rates (Harlan, 1958).

Specialized grazing systems such as the deferred rotation or rest rotation systems can improve range condition and increase forage production on most Montana ranches. As range condition improves, the range can sustain greater livestock numbers, the production per individual grazing animal can increase, or both may occur. The degree to which livestock production is improved will be influenced by past grazing management and the range condition.

Literature Cited

Anderson, E. William. 1967a. Grazing systems as methods of managing the range resources. J. Range Manage. 20:383–388.

Anderson, E. William. 1967b. Rotation of deferred grazing. J. Range Manage. 20:5–7.

Harlan, Jack R. 1958. Generalized curves for gain per head and gain per acre in rates of grazing studies. J. Range Manage. 11:140–147.

Hormay, A. L., and M. W. Talbot. 1961. Rest rotation grazing—a new management system for perennial bunchgrass ranges. U.S. Dep. of Agr., Forest Serv. Prod. Res. Rept. 51. 43 p.

Houston, W. R., and J. J. Urick. 1967. Response of range cows and calves to improved spring pastures. Proc. of West. Sect. Amer. Soc. of Animal Sci. 18:231–236.

Ratliff, Raymond D. 1962. Preferential grazing continues under rest rotation management. U.S. Dep. of Agr., Pacific Southwest Forest and Range Exp. Sta. Res. Note 206. 6 p.

Range Management, Conservation, and the Objectives of the American Society of Range Management: An Opinion

Too long have the American Society of Range Management (ASRM) and workers in the range management field overlooked differences in range philosophy. Most of us have labored with the idea that though our techniques may be different, our goal was the same—conservation. A highlight of the 1970 ASRM Convention was the discussion in which panel members sought to define range and range management, and tried to formulate these into the role and objectives of the Society. This discussion led me to the conclusion that there are widely different philosophies in range management, that there may be many different conservation objectives, and finally that there are several potentially different roles for the Society. The role of the Society as a forum was mentioned by several panel members; this is perhaps the most important way the Society can truly be dynamic—to openly discuss diverse viewpoints of range management philosophy, rather than being merely a podium for presentation of research papers.

Range Defined

To set a framework for the discussion to follow (and following the format used at the convention) we need to agree upon the definition of range. Defining range would probably prompt as many definitions as there are Society members. Each definition seems invariably to have exceptions or special inclusions because of past cultivation, rehabilitation work that involved cultivation (albeit with specialized equipment), woodlands, and many others. Virtually every definition presented by the panel raised additional questions. What is open space? What are wildlands? How do woodlands fit in? What about greenbelts left near urban areas by zoning actions?

The definition of range should be brief and simple, yet all inclusive. The key, I believe, is that it must include grazing. This is the historical concept of range, and despite a proliferation of new uses and recognition of other values, the basic tenent that separates our Society from others is grazing. Thus, my definition of range is simply that it is grazable land which is not continuously or periodically cultivated. For the purposes of the Society we should not worry about whether range is grassland, or how to catagorize forested lands. We should not worry about how to define open space, or whether to separate between domestic livestock or wildlife species. If it is grazed, it is range. This definition carries no implication of what the land may be best suited for, nor should it. Often, for example, cutover timberlands are grazed until timber reproduction lowers forage production to a level where it is no longer economic to graze it. But in the interim, it is range, and can be managed as such. Further, separation between pasture and range is, in my opinion, largely an academic exercise because of the blurring caused by advancing technology in cultural practices and the return of several million acres from grains to permanent pasture.

Objectives

I believe a more critical discussion is to come to grips with objectives. The definition and objectives of range management, and the objectives of the ASRM need to be discussed almost simultaneously. Only after we have agreed upon all of these can the role of the Society be developed.

Each member of the Society, I suspect, has his own concept of the objectives of range management. Objectives concerning range are built up through education, experience, and exposure to the techniques of an employer. These three E's culminate in a range management philosophy for the individual. Most have probably never formalized it, but it is there. And the member will often believe the Society's role should be to promote this philosophy.

Because the objectives of range management, and hence of the Society, get tangled with the objectives for rangelands of the individual user or of the member's employer, every definition eventually, for the sake of harmony, falls back to saying we are for "conservation," or "wise use." But what do these terms mean? How can they be applied? This, in my opinion, is the point where all definitions break down. We need to be able to define conservation in a way that will satisfy all members of the Society, all sectors of the economy, all resource users, and all interest groups. But rather than meet head-on the definition of conservation, we sit back thinking all is well because we are all for the same thing. I submit that we are not; and further, that we, as a Society, cannot define conservation in general terms which have specific application or is meaningful.

Examples of Conservation

There are many levels and kinds of conservation; and each in its own way may be good, provided it meets the objectives of the person applying it, and it produces the benefits he desires.

For example, the livestock producer has objectives. In applying "conservation" he wants to be able to produce quality animals, in sufficient quantity to make his operation pay, and have a continuing forage supply each year. But his "conservation" will often, even when his range has grass stirrup-high, tend to minimize or overlook the externality of producing wildlife habitat. He may derive personal satisfaction from the presence of wildlife, but unless he realizes a cash benefit from them, there is no reason why he should consider them. The result is that he applies treatment practices to the range that will maximize livestock forage production. These practices may include a grazing system that favors grass species, and cultural practices to reduce vegetation which he considers undesirable and competitive with livestock forage. "Conservation" may produce external diseconomies, too. One of the myths of "conservation" is that it is always good for everyone. But, for example, some cultural practices can reduce runoff by increasing infiltration, and result in reduced runoff into irrigation storage ponds on downstream property. Thus, while "conservation" may be good for one, it may produce negative benefits for another.

On another side, the wildlife habitat manager has different objectives from the livestock producer. Looking at the same range landscape as the rancher, he would apply "conservation" in a wholly different manner. He would adopt grazing systems which would favor browse species—if he allowed livestock grazing at all. (This is another myth of "conservation," but the subject of another paper: that livestock removal can, by and of itself, improve the quality of wildlife habitat.) He might remove small patches of woodland so as to provide openings and edge effect, but certainly there would be no large scale removal of what the rancher would call undesirables. He might plant browse, but he would want to minimize competition from grass.

On yet another side, the watershed manager might apply another "conservation." His "conservation" would depend upon his objectives. This could be to either increase or decrease water yield. If it is the former, he might clear streambanks of phreatophytes, and he would do no practices which would impede overland flow of runoff. Contrawise, if he wished to decrease discharge and yield, he would manage the bottomlands to encourage phreatophytes so as to increase channel roughness and thereby reduce velocity by instituting a grazing system to favor them. He might try to induce aggradation of gullies so as to spread flows and promote more infiltration on the flood plain. His grazing system would also be aimed at changing soil bulk density on the uplands to promote greater infiltration. And he might apply treatments such as contour furrowing aimed at withholding runoff from the drainage net of the basin. Either path, in context with his objective, could be, and is, called "conservation."

It should be obvious that while each profession applied "conservation" they end up with an entirely different landscape, an entirely different plant composition, and essentially a different range resource. Yet each applied what he considered "wise use" and probably would derive multiple benefits from his treatments, although they would be wholly different in character.

My point is that "conservation" or "wise use" cannot be defined to the satisfaction of all. Each segment of the Society has their own definition, and thus, has their own definition of range management. And if we can't even agree on what range management is, how can we agree upon objectives for the Society?

Range Management

At this point I would like to point out several things that, in my opinion, range management is not, and to propose that the Society be ever alert not to fall into the trap of looking at them as management.

Range management is not artificial treatment such as seeding or brush control. These are tools, not ends in themselves. They may be used to speed ecological change, but actually their application is merely an admission that our previous management, or lack of it, has failed. And in many cases, their application is fighting ecology. We cannot convert a deteriorated site back to what it was or might have been 100 years ago. Soil has eroded, and the site, being dynamic, is far different now, and has a far different potential.

Range management is not simply changing range use to a dormant season of the desired vegetation.

Range management is not removal of grazing animals.

Range management is not simply the reduction in numbers of animals per unit of area.

Yet all of these philosophies were commonplace in the Society's photo contest in Denver, and one must conclude that they represent the thinking of at least some of the members. Virtually all of the condition and trend photos showed land treatment—not the results of management through the manipulation of grazing use; or they showed fence-line contrasts—non-use vs. abusive use.

Range management is, I believe, a positive manipulation of grazing use, undertaken with specific objectives in mind, to achieve a desired level and kind of benefits. It is the application of a prescription to the range—to accommodate or enhance its present use, and to achieve a desirable vegetative composition—within the context of grazing use. It is not the application of cook book grazing formulas, but rather the application of principles. Different grazing systems have different principles (though I find many who will not admit it), and result in different vegetative compositions. The rancher may apply a grazing system on his private lands to favor grass species. The multiple use manager of public lands might apply different principles and a different grazing system to achieve benefits not only to livestock forage, but to wildlife, watershed, and/or timber production. Grazing systems will vary with the type of vegetation, and will vary with the objectives being sought.

It is time the Society had the maturity to accept the idea that different grazing systems have different principles; that there is more to range management than light, moderate, and heavy grazing use; that there are differing objectives in range management which call for different grazing systems; and that "conservation" without further definition is meaningless.

Someone once said people are for conservation regardless of what it means. Most definitions are emotional and akin to motherhood and the flag. I feel strongly that we recognize that each use of the range resource can at once be complimentary, supplementary, and conflicting with other rangeland uses. It is the job of the range manager to sort out the uses he wishes to manage for, and to determine the benefits he wishes to achieve from his program. We need to be definitive by not being just for conservation, but by being for the application of grazing management principles applied toward specific range and land management objectives.

Summary—Definitions

Range is defined simply as grazable land which is not continuously or periodically cultivated.

Range management is the application of grazing management principles toward specific objectives to produce desired benefits. These objectives may vary with land ownership (as mentioned in Mr. Connaughton's statement of Society objectives, and as I have implied). This definition, while brief, should embrace all of the conflicting segments of our Society. The essential element is that range management be concerned with grazing management. It gets away from range management being "conservation." It recognizes the fact that range management may have different objectives, or may have objectives concerned with securing benefits beyond livestock forage, in areas such as wildlife habitat, water yield, sedimentation, and any others which can be influenced by the manipulation of grazing animals.

The Society's role is to provide a continuing forum to discuss the application of grazing management principles, and to aid all members in their search for the best methods to achieve specific objectives in range management with grazing animals.

It follows, then, that the objectives of the Society are to promote this forum, and to promote the application of grazing management principles to secure the greatest level of benefits from all rangelands consistent with the objectives of the land owner or administrator.

Conclusion

These definitions and statements are neither a "cowboy" philosophy nor a lack of recognition of the other uses of the range. It is simply stating that the Society has a niche to fill, and it should fill it. By interposing itself in all other resource uses it dilutes its effectiveness in the very area where there is no other organization that can better function. By accepting a limited role for the Society we make it stronger. We can still provide a forum for such items as recreational uses of the range—but it would be in the context of how to make the two more compatable. We can still discuss range–watershed management, but in terms of the hydrologic consequences and implications of various range management treatments. And the same would apply to other uses as well. While a narrow view of range and the Society's role, this umbrella seems to me to be broad enough to include allied uses and interest groups, but the Society would embrace them in the context of grazing use, not in the context of eliminating or curtailing grazing to accommodate them.

As it approaches its twenty-fifth year, the Society must be dynamic, must accept change, and must be willing to go beyond just being for "conservation."—*Gerald E. Hillier*, Billings, Montana.

Herbicides

The volume of literature on the use of herbicides on rangelands is quite large and growing. In this body of literature it is rare indeed to find any consideration or discussion of the ecological impact of herbicides on the environment. It is relatively safe to state that effects on non-target flora and fauna have been of little or no concern. A review of papers on herbicides that have been published in the Journal during the past 5 years substantiates these statements.

The public is becoming more alarmed about environmental quality and papers and discussion on this topic have been presented at ASRM meetings for the past several years. However, these discussions and papers seldom appear in the Journal. It is gratifying to note that the theme of the 24th annual meeting of the ASRM is "Rangeland Environments and Man." One of the perennial sessions at our national convention is titled "Range Improvements," and one is planned also for the 24th convention. It will be interesting (considering the theme) to see if any of the papers on herbicides that undoubtedly will be presented at this session discuss or consider environmental factors other than forage production.

In the past decade the literature has been flooded with papers and editorials that bitterly protest and decry the use of herbicides on wild lands. These papers have not all been prompted by emotional interests but come from many sources with a genuine concern for environmental quality. In view of this, it doesn't speak well for the Society when the Journal is prefaced with pictures of airplanes spraying sagebrush (May 1969 and November 1968 issues).

Research efforts are predicated on an ever-changing philosophical framework. When this framework changes it follows that research efforts should also change. Range management philisophy is progressing successionally toward maturity. Range research, however, has not kept abreast—the production of more forage is still the main concern. Environments have been (and still are) modified, altered, or destroyed to produce more livestock forage without regard for the effects on the total environment. In nature there is neither reward nor punishment—just consequences!

The philosophy that rangelands are unproductive unless they are producing a maximum amount of livestock forage has been dead for some time. The typical land manager today thinks in terms of a balanced resource—diversified communities—that will yield more than one product. Spraying and artificial treatments that reduce diversity can seldom be justified. Diversity and variety are cornerstones of survival since the more ways there are of consuming or of being consumed, the more favorable the chances of a living population to avoid high fluctuations in the birth and death of individual species.

Agricultural practices that reduce the diversity of species in a community may be working in exactly the wrong direction. A healthy diverse biotic community is not easily invaded by exotic forms of either flora or fauna and has considerable ability to adjust to invaders.

The interaction of a herbicide with the environment begins at the moment of application. Interaction occurs in the atmosphere, on and beneath the soil, within plants, and within and among every other living thing found in the target area.

We lack complete knowledge of the environmental factors regulating herbicidal performance or for limiting herbicidal use. We have only partial or speculative answers. Since pollution has been defined as human disturbance of the cycling of energy and materials in natural systems, herbicides may be classed as pollutants.

Defenders of herbicides hedge on their safety. They make such statements as "There is no evidence they are directly damaging." They have been tested on various animals—mostly mice and rats. There have been few tests on humans. Evidence, however, is accumulating that herbicides are not as harmless as we have been led to believe. The Denver Post recently published reports that defoliants may have caused deformities in Vietnamese babies. President Nixon's Science Advisor, Dr. Lee Dubridge, has reported that offspring of mice and rats exposed orally to 2,4,5-T showed a higher-than-expected number of deformities.

There is evidence that herbicides have increased the nitrate concentration in streams in excess of the limit set for potable water. There is also evidence, because of the added nitrates, that algal blooms have occurred in streams where none were known to have occurred previously.

A University of Idaho Extension Bulletin lists 100 herbicides that have extensive-to-minor usage within the State of Idaho. Over 20% of the chemicals listed were very-toxic to moderately-toxic. Almost 30% of the dermal-response ratings range from absorbed-and-poisonous to moderately irritating. This bulletin refers to the strict safety requirements of HEW, the USDA, and the Idaho Department of Agriculture regarding the use of herbicides and pesticides. The finale includes a statement from the California Medical Association. They testify that, among other things, herbicides and pesticides constitute only a moderate health hazard. Shades of Rachel Carson! ! !

We tend to require detailed scientific proof of direct personal damage to man as a prerequisite for even considering any restriction of the right to use herbicides or pesticides. A doctor or a lawyer even suspected of malfeasance is immediately suspended from practice until the facts are known. There is a strong philosophy (aided and abetted by the chemical companies) that since herbicides have not been proven damaging, there is no reason to restrict their use until such proof is forthcoming. So strong is this philosophy that many of our leaders in range research consider it their right to spray and keep spraying.

This rather sad and appalling situation is aptly represented by a recent issue of a monthly newsletter on range management. It is edited and written by a leading range extension specialist in cooperation with a state university. "Brush Control—1970" is the title of the feature article. I quote the first sentence—"It's that time of the year again." Then follow 6 pages of recommended procedures for more effective spraying. There is not one word on those 6 pages that expresses any recognition or concern for non-target flora and fauna.

Jack Hooper from Utah State University stated it mildly when he said "Unless the present range philosophy is transported through space or the range manager undergoes some change, or a new philosophy is evolved, the field of range management will die a slow, gruesome death." I do not agree with Jack. It will be quick, quiet, and no one will care.

The interactions that occur due to herbicidal or other agricultural treatments is complex beyond belief, yet other disciplines with similar "impossible" problems and complexities have forged ahead. Consider the entomologists and their methods on integrated control of insects, or look to the biologists who isolated and synthesized the juvenile hormone in insects. Looking farther, consider the challenge and the depth of effort expended by the biochemists and geneticists who broke the genetic code.

Range management as a science will not survive unless it adopts a meaningful philosophy and understands that any science that relates to the land resource cannot stand alone, or isolate itself structurally by concentrating within a narrow single use field. Range science will not survive if it continues to wear blinders—a cow is not very tall —someone should be able to see over its back.—*Thomas H. Heller*, Range Conservationist, Bureau of Land Management, Denver, Colorado.

What Has Range Management Done for Recreation—Lately?

Rangeland is being used for recreation, and it is going to be used more by people seeking new and stimulating ways to utilize their growing leisure time and enjoy their increasing affluence. But the reason range men should care about recreation is broader and deeper than the obvious one stemming from the use of rangeland for recreation.

The urgent reason we should care is rooted in the inescapable conclusion that range men (along with kindred professions) have a responsibility for the environment in its broader sense that stems from their rather unique ecological qualifications. This environmental responsibility has many facets, and some of them are being met quite well, but others are not being redeemed to the extent they ought to be. Perhaps the basic failure results from the reluctance of the range man to leave his own comfortable professional environment among his fellow specialists and the grass and livestock. There have been signs in recent years that some range men are actually trying to draw even tighter boundaries around the field of range while stating even more restrictive definitions of range management. This trend is deplorable because it comes at a time when just the reverse ought to be happening.

This is a time when Americans have suddenly become aware of their environment—they have just discovered it, so it seems. There is a new breed and it is full of concern for its surroundings. The New Ecologist is articulate in voicing these concerns, particularly in terms of criticism for what land users and land managers are doing. These folks are worrying about some things we all *should* worry about, but they are worrying about some of the wrong things too. Their leaders and spokesmen include a lot of people well qualified ecologically, but there are some who are marching off in intellectually diverse directions, contributing little to the solution of our environmental problems. This is where the range man—and other wildland ecologists—come in. Or they *ought* to come in. The question is: shouldn't the professionals with a proven background in applied ecology shoulder the responsibility born of their knowledge and commence to communicate about environmental ecology—and assume leadership roles in more active ways? Doesn't anyone with a *real* ecologist's credentials have an obligation to forsake specialization and become a generalist to the extent that he can provide voice and leadership to the Nation's environmental concern?

The value of outdoor recreation depends quite heavily upon the quality of the environment in which it takes place. Hence, the range manager can make his most immediately obvious contribution to the recreation user in terms of what he does about environmental management. This certainly starts with the range animal habitat shared by the recreationist, but it must not stop there. The range man must swing a wider loop, or somebody else is liable to do the roping for him.

At the same time the range man is broadening his horizons, the recreation manager is well-advised to turn to practiced ecologists for estimates of site capacity and tolerance and for advice about how recreating man fits into existing ecosystems, whether wilderness or picnic site. Such consultation will avoid more monuments to overlooked ecology.

The range-recreation symbiosis wasn't recognized at the outset. When the range man first began to see recreation use intruding upon his comfortably staked-out habitat, his tendency was to regard the new use and user as competition, and the recreation user and manager usually responded with the same attitude that characterized early sheep–cattle wars. Happily, there has turned out to be more compatibility than competition. Opportunities have been seized to utilize areas fenced for seasonal recreation use as part of intensive management systems where grazing takes place outside the recreation season. Water systems developed for recreation sites provide livestock water. Recreation users find that livestock and ranching operations add measurably to their outdoor experience, and dude outfitters have capitalized on this at elaborate "spreads" as well as on wilderness trails all over the west. This isn't to say that recreation on the range is, or will be, free of conflict. We must recognize there are places where range activity will have to move over for recreation, and others where recreation will have to make way for grazing use. There will be fewer irreconcilable conflicts if lawmakers and policymakers resist the thrust toward separate management of each resource and total allocation of land to individual uses. This thrust is surfacing in recreation, but not there alone. Management in a vacuum may be the easy way, but it serves the public poorly.

Wilderness can still be an area of tension between range use and recreation use. Competition for forage between recreation stock and range livestock will occur—even intensify. But the problem isn't a new one; it just involves different owners and users of stock. The evolution of wilderness management (which is a great deal broader than recreation management because a wilderness is more than just a recreation area) has placed some limitations on how livestock will be managed, and what kind of improvements will be involved. This still causes friction. And land managers have been accused in the halls of Congress of being more concerned about livestock than people, while being criticized by New Ecologists and others for maintaining grazing in the wilderness framework.

Because some grazing operations in some wildernesses are economically marginal, or because human impacts from recreationists will grow in some areas, people-use may well supplant livestock use. The challenge to range managers in those cases then, is to build the capacity elsewhere to replace that on land where grazing is preempted.

Range men have done a lot of this kind of enhancement, either restoring depleted rangelands or making good sites produce even better. But in the process, some crimes have been committed against the landscape. Sensitivity to environmental amenities including natural beauty has not marked all type modification projects, particularly the earlier ones.

But, as range improvement becomes more sophisticated, its mark on the land is easier on the viewer's sensibilities. Treatment which follows nature's lines, either topographic or edaphic, can *help* some landscapes rather than hurt them. It is essential that future projects involve design principles applied by landscape architects to enhance scenic values. Certainly such an alternative is preferable to a non-use or no-treatment approach which might be forced upon us should we neglect nature's lines and substitute obviously man-made ones. People are watching what we do, and if they don't like what they see, they will "see us in court."

New techniques to clean up after ourselves are going to be needed if type modification is to be compatible with esthetic quality. Fire has been used to good advantage, but it can produce a result that is not always beautiful. And we have a responsibility not to make adverse contributions to the environment's air.

Chemical applications for plant and insect control are another sensitive environmental area that worries recreation users and the citizen–ecologist. Range men have probably been more sensitive to the potential problems of chemical additions to the habitat than many others who have used them.

Looking ahead, the challenge to the range man is several-fold. He needs most of all to redeem the responsibility born of his ecological expertise by making his knowledge available and providing leadership to those who are concerned about the wildland environment in which they live and recreate. That same expertise must be continually refined and sharpened to enable range use and recreation use to increasingly and compatibly share overlapping habitats. Finally, the range man must strengthen his concern for the impacts of his own work upon the landscape, forming new teams with landscape architects to assure that the environmental amenities—as well as range productivity—are benefited by what is done in the name of range improvement.—*R. M. Housley, Jr.*, Assistant Director of Recreation, Forest Service, U.S. Department of Agriculture, Washington, D.C.

BOOK REVIEWS

Resources and Man. A Study and Recommendation by the Committee on Resources and Man, National Academy of Sciences–National Research Council. W. H. Freeman and Company, San Francisco. xi +259 p. illus. 1969. $5.95 clothbound, $2.95 paperbound.

This book, relatively brief and nontechnical, is the report of the special NAS–NRC committee set up "to evaluate national and world resources in the light of current and expected stresses and to identify problems in need of study as well as opportunities for progress."

The committee's recommendations are presented in Chapter 1 as 26 specific steps, grouped under the general headings of Early Action (example: *That detailed assessments of the actual and potential agricultural and forest lands of the world and their classification into best-use categories be undertaken . . . .*); Policy (example: *That the efficiency and capacity of agricultural productivity, both in the United States and abroad be increased to the maximum levels possible.*); Research (example: . . . *the formation of another group to study the various social, psychological, legal, medical, religious, and political aspects of the problems of resources and man . . . .*); and Organization (example: *That there be established, at an appropriate location within the United States government, a high-level group of broadly qualified resource specialists and ecologists . . .*).

It is indicated that the functions of such a high-level group would be (a) ... continuing surveillence of both nonrenewable and renewable resources; (b) to inform . . . (of) impending shortages, . . . environmental deterioration, and other prospective developments concerning natural resources; and (c) to recommend . . . well in advance of crises optimum courses of action. . . .

In Chapter 4, "Food from the Land," author Sterling B. Hendricks, Mineral Nutrition Laboratory, USDA, gives significant recognition to rangelands, pointing out that "grasslands and open bush . . . are deeply interwoven with the developments of man," and that although the initial reserve of such lands is now practically gone (i.e., have been giving over to cultivation and other uses), the present grazing lands do play an important part in the animal component of food production.

Recognizing that most of today's natural grazing lands are "generally less watered, steeper, at higher elevation, or more stony," Hendricks emphasizes that management is essential not only to prevent degradation but to improve their productiveness. Fertilization, he states, can help on many grazing areas although some other factor is apt to be limiting. Likewise, range plants can be improved, but management to prevent overgrazing and to control brush is a more likely first factor of production.

Resources and Man is much broader in scope than is indicated in this short review. It also presents some long-range views that are well worth the attention of those engaged in the research, management, administration, or use of land resources.—*Francis T. Colbert*, Denver, Colorado.

Arizona Range Grasses. Robert R. Humphrey. The University of Arizona Press, Tucson. 159 p. illus. 1970. $3.50.

The genesis of this present work lies in Arizona Agricultural Experiment Station Bulletin 243, *Common Arizona Range Grasses*, by Robert R. Humphrey, Albert L. Brown, and A. C. Everson; it first appeared in 1952 and was reprinted in 1957. In 1958 an enlarged revision appeared as Bulletin 298, *Arizona Range Grasses*, with Humphrey as the single author.

Carrying the sub-title "Their Description, Forage Value and Management," the book describes 71 range grasses important to Arizona, and indicates briefly their identifying characteristics, seasonal forage values, and the management practices required to maintain each in a productive condition. Additionally, a short paragraph headed "Occurrence" tells the counties in which each species is found and describes its adaptability to site conditions.

There is a helpful introduction titled "Grasses and Grazing," which states, in part: "A knowledge of the functions of the roots, stems, and leaves of grass plants is of value to continued, profitable range management.

"One of the principal goals of range management is to develop a system of grazing that will utilize the plants during the period of maximum nutritive value . . . without injuring the plant.

"The rancher . . . can become acquainted with the different grasses on his ranch, the growth cycles, and their feeding value. He can devise a management plan that will maintain or improve his range while maintaining a high level of animal nutrition."

Format of the book is good; the write up for each grass is confined to one page, which faces the accompanying drawing. The book is a "paperback," but is very well printed on good white stock that greatly enhances Lucretia Breazeale Hamilton's magnificent line drawings. Included also are a bibliography and common name index.—*Francis T. Colbert*, Denver, Colorado.

FAO PUBLICATIONS

MANAGEMENT AND USE OF GRASSLANDS, DEMOCRATIC REPUBLIC OF THE CONGO by S. A. Risopoulos is primarily a general review and description of (1) cattle raising, by both Africans and Europeans, in the Congo, and (2) the work being done at four research stations in as many different regions. In outline form, supplemented with tables and illustrations, this work presents an overview of the geography, climate, soils, and vegetation of the four regions, comments on the status of pasture management, forage crop production, and animal husbandry methods, and makes recommendations for changes in grassland management and for additional research necessary. Pasture and Fodder Crop Study No. 1, FAO, Rome. 168 p. illus. 1966.

PRINCIPES, MÉTHODES ET TECHNIQUES D'AMÉLIORATION PASTORALE ET FORRAGÈRE EN TUNISIE by Henri-Noël Le Houéron is somewhat the same type of work as the above, but focuses more strongly on the description and management of various land types: *prairies* (*naturelles et artificielles*), *parcours*, *pâturages semés, etc.* Pasture and Fodder Crop Study No. 2, FAO, Rome. 291 p. illus. 1969.

Other recent FAO publications of general interest include:

TOWARD A STRATEGY FOR AGRICULTURAL DEVELOPMENT, Basic Study No. 21, ix + 66, 1969; THE STATE OF FOOD AND AGRICULTURE, viii + 205, 1968; and 1968 PRODUCTION YEARBOOK, xvi + 814, 1969. All FAO publications may be obtained through UNIPUB, INC., P.O. Box 433, New York, N.Y. 10016.

OTHER PUBLICATIONS

GUIDE TO THE IMPROVEMENT OF ARIZONA RANGELANDS is the product of many years of effort by the Arizona Interagency Range Technical Subcommittee. It is intended as a practical guide to technicians and ranchers in the planning and application of proper range use, brush control, range seeding, and range fertilization practices. Additionally, the publication classifies and describes eight major land resource areas in Arizona, and 27 different environmental zones within the various areas. It is a comprehensive and most useful publication for any rangeman working in the Southwest. Bulletin A-58, Cooperative Extension Service and Agricultural Experiment Station, The University of Arizona, Tucson, 1969.

SAINFOIN SYMPOSIUM, Montana Agricultural Experiment Station Bulletin 62, 1968. Thirty-one papers presented during a two-day sainfoin symposium (December 12 and 13, 1968) are published in the bulletin edited by C. S. Cooper and A. E. Carleton. Approximately two-thirds of the contributions are from Montana. The other contributions are from Canada, Romania, Idaho, Washington, Nevada, Wyoming, and the Nitragin Co. Topics discussed include nodulation; seed germination; seed production; winter-hardiness; performance under irrigated, dryland, and range conditions; nutritional value of the forage as measured by laboratory techniques and animal performance; diseases; insects; weed control; soil fertility relationships; cytogenetics of sainfoin (*Onobrychis viciaefolia*) and related species; and breeding objectives. Since new interest in sainfoin as a forage crop in the United States has occurred in only the past decade, the results of most papers are preliminary. (*C. E. Townsend*)

You might think that a book entitled TURFGRASS SCIENCE would have little, if any, value to people in the professions of range management and range science. All of us have at least a non-professional interest in the turf about our homes. For this reason alone, the new book edited by A. A. Hanson and F. V. Juska is a valuable addition to our personal library. In addition, TURFGRASS SCIENCE includes some chapters that are just as important to the range manager as to the turfgrass scientist. For your professional interest in grasses, I recommend especially Chapter 7, Physiology of Growth and Development by V. B. Youngner, and Chapter 8, Ecology and Turf Management by R. E. Schmidt and R. E. Blaser. Here you will find important discussions about grass morphology, physiology, and ecology. To you, the excellent morphological descriptions will be incomplete because they are directed only to the turfgrass type of growth; and the ecological factors discussed are narrowly specific to turf. In addition to these chapters, you surely will be interested in the identification of grasses by vegetative characters found in Chapter 13, Species and Varieties by A. A. Hanson, F. V. Juska, and Glenn W. Burton; in Turf Weeds and Their Control; in Nutrition and Fertilizers; in Producing High Quality Seed. As you would expect, the book includes chapters on turfgrasses for semi-arid and arid conditions, insects, diseases, irrigation, putting greens, highway roadsides, athletic fields, planting methods, and many others—a total of 28 chapters. So, take a good look at this book for both professional and non-professional interests. Then keep it handy as a good reference. Each chapter includes a long list of references; and specific items of interest are located easily in the index. Agronomy Series No. 14, 715 p., 160 fig., 73 tables, $10.00 to ASA members, $12.50 to non-members, American Society of Agronomy, 677 South Segoe Road, Madison, Wisconsin 53711.

Two new Proceedings are now available: TALL TIMBERS FIRE ECOLOGY CONFERENCE, Proceedings No. 8, Tallahassee, Florida, March 14–15, 1968. This 285-page paperback contains 15 exceedingly interesting and authoritative papers on fire, its uses and effects in selected parts of five continents—North and South America, Africa, Australia, and southeast Asia. Obtainable from Tall Timbers Research Station, Route 1, Box 160, Tallahassee, Fla. 32301. The second report is for those who are interested in the Alps and can read French—an account of Le Congres de Divonne in Bulletin No. 18 of the FEDERATION FRANCAISE D'ECONOMIE MONTAGNARDE. The meeting and tours were held at Divonne Sept. 27–Oct. 1, 1968. Although the theme primarily dealt with trees, the volume includes reports on grazing and tourism. Obtainable from Federation Francaise D'Economie Montagnarde, Maison de la Montagne, 81 Vabre(Tarn), France. (*R. S. Campbell*).

Evaluation of the Present Status of DDT with Respect to Man.

A statement developed by the Committee on Toxicology, Council on Occupational Health, American Medical Association.

(Reprinted with permission from the Journal of the American Medical Association, Vol. 212, No. 6, May 11, 1970.)

Because of the great concern expressed by physicians, legislators, scientists, conservationists, and others, the Council on Occupational Health and the Council on Environmental and Public Health of the AMA reviewed the DDT problem with as much realism as is possible. In this regard, the two Councils believe that certain facts have been established. For instance:

1. DDT, when absorbed in doses or concentrations exceeding certain limits, is toxic. In man and other mammals DDT's primary effects are on the liver and central nervous system.

2. Extensive studies by several investigators have shown that a small concentration of DDT and its metabolites is present in the fatty tissues of many people in all walks of life. However, there has been no significant increase in the storage of DDT by the general population in the United States since it was first measured in 1950. Pesticide handlers who have been studied with great care during the past 30 years have concentrations in fat as much as 50 times as high. Yet, careful research has shown no interference with their health despite long-continued exposure. Injuries to humans have been observed only in persons who accidentally received acute massive doses.

3. From animal experiments it has been shown that DDT, when retained at elevated concentrations in the tissues (the critical level is unknown), stimulates the microsomal enzyme system. This effect is modified, and is likely to be more marked, if additional organochlorine pesticides or certain drugs are absorbed in addition to DDT. Increased activity of the liver microsomal enzyme system undoubtedly affects the rate of metabolism of pesticides and certain drugs.

4. In some regions, surface and ground waters have been contaminated by DDT through runoff from treated areas, percolation from soil to ground water, waste discharge, accident, and other means. Fish-kills have been traced directly to high concentrations of DDT and other pesticides in stagnant as well as in flowing waters.

5. It has been shown that DDT interferes with marine life, and that it concentrates in certain marine organisms. It has been equally well established that DDT affects the hatching ability of some birds, including eagles, pelicans, and falcons, and probably affects others.

A number of general accusations and anxiety-provoking statements about the health hazards of DDT have been made from time to time. In our opinion, the following are speculations as yet unproved:

1. That DDT significantly reduces photosynthesis in phytoplanktons.

2. That the concentration of DDT will continue to increase in living organisms for many years.

3. That DDT as used at present influences human reproduction.

4. That DDT, as used at the present time, will control the population explosion, by destroying "all chlorophyl formers and hence all food supply," or by its effects on the sex hormones.

5. That DDT is carcinogenic to man.

We are often on insecure ground when we extrapolate experimental or other data from animal to man. Such extrapolation becomes almost unrealistic when it is based on only one species of animal. Animal studies are important as guides, but the final answer must be found (via experiments or otherwise) in man himself. To give only one example: Street's work with rats showed that the combined intake of DDT and dieldrin markedly reduced the retention of dieldrin in fatty tissues.[1] Deichmann and associates, working with beagles, showed the opposite—that the combined intake of DDT and aldrin (metabolized to dieldrin) have little effect on retention of dieldrin in body fat and blood.[2] Furthermore the combined intake of DDT plus aldrin markedly increased the retention of DDT and metabolites in these tissues.

Although DDT has an effect on the thickness of eggshells, it has not yet been proven whether this is the effect of crude or pure (o,p′ = or p,p′ =) DDT alone, or of DDT in combination with something else, perhaps another pesticide. The eggshells of many species of birds apparently have not been affected.

The studies and reports by Hayes,[3] by Upholt and Kraybill,[4] and by Durham[5] presented no evidence that the long-term absorption of traces of one or more of the synthetic (nonmetallic) pesticides induced illness. The studies on human autopsy tissues by Deichmann and Radomski,[6] and by Radomski, Deichmann, and Clizer[7] demonstrated that individuals who used pesticides indiscriminately showed elevated concentrations of DDT and related pesticides in their tissues. The elevated concentrations were found largely in persons who had terminal diseases, including cirrhosis of the liver, carcinoma, hypertension, and atherosclerosis. However, the investigators did not demonstrate a causal relationship between those diseases and pesticide retention in body tissues.

The Council on Occupational Health and the Council on Environmental and Public Health, after considering the above known and speculated effects as well as the comments given above, recommend that:

1. The indiscriminate use of DDT and other toxic materials is to be deplored and should be stopped. Industry should be urged to hasten the development of more specific pesticides which persist only long enough to accomplish the planned purpose. Research also on nonchemical methods of pest eradication and control should be expanded.

2. The use of DDT should be continued for the control of human diseases transmitted by DDT-susceptible vectors, such as malaria and typhus, in the United States only when other measures, including the use of less persistent or less harmful insecticides or other control measures, are ineffective, or where the benefits of using DDT instead of such other insecticides or other measures clearly outweigh the disadvantages. Whenever used, careful consideration for effective dosage, proper application, and other precautions should be observed. Efforts to find a less hazardous means of control should be continued and expanded.

3. The use of DDT should be continued for the control of pests on crops for which, at this time, no adequate alternative is available.

4. The use of DDT should be limited or discontinued in those areas in the United States where organochlorine pesticide pollution has created a true problem in the survival of wildlife, birds, and fish, or where it has (for other reasons) seriously endangered the ecology. In other words, in each instance where the use of DDT is being considered (agricultural and forest areas), the advantages should be weighed against the disadvantages of causing local pollution or pollution of the run-off waters.

5. In addition to the stringent enforcement of tolerances established by the FDA, the use of DDT and other pesticides should be subject to such governmental regulations as are required for the protection of the population at large and for the prevention of pollution. Adequate staff and money should be provided to enforce such laws and regulations and to conduct the studies necessary to keep regulations abreast of advancing knowledge of pesticide technology, effects on human health, and the broader ecological implications of the use of pesticides.

6. The education of the public in general and of the pesticide worker in particular should be expanded, so that DDT and other pesticides will be used with adequate caution and respect.

References

1. Street, J., F. Mayer, and D. Wagstaff. 1969. Ecological significance of pesticide interactions. *Industr. Med. Surg.* 38:409–414.
2. Deichman, W., M. Keplinger, I. Dressler, et al. 1969. Retention of dieldrin and DDT in the tissues of dogs fed aldrin and DDT individually and as a mixture. *Toxic Appl. Pharmacol.* 14:205–213.
3. Hayes, W., Jr. 1969. Pesticides and human toxicity. *Ann. NY Acad. Sci.* 160:40–54.
4. Upholt, W., and H. Kraybill. 1969. Ecological effects of pesticides. *Ann. NY Acad. Sci.* 160:55–60.
5. Durham, W. F. 1969. Body burden of pesticides in man. *Ann. NY Acad. Sci.* 160:183–195.
6. Deichmann, W., and J. Radomski. 1968. Retention of pesticides in human adipose tissue. *Industr. Med. Surg.* 37:218–219.
7. Radomski, J., W. Deichmann, and E. Clizer. 1968. Pesticide concentrations in the liver, brain and adipose tissue of terminal hospital patients. *Food Cosmet. Toxic* 6:209–220.