MANAGEMENT to increase FORAGE PRODUCTION in the West

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Management of forage crops for increased production in the West must take into account the wide diversity in climate, soils, and topography that influence land use and type of farm or ranch enterprise. Large areas of land have low capability for use because the climate is arid or semiarid, and other large areas of land are nonarable because they are steep or rocky or both. These are the range and timber lands of the West. Interspersed among them are the farmed valley lands and a few arable plateaus. Many of the valley lands are irrigated.

The principles for managing forage crops for increased production in the West are similar to those used in other parts of the Nation, but the procedures are often different. Management is based on the physiology of the plant species and on the ecology of the plant community in the case of pastures and ranges. The aim of management is optimum yield of high quality forage per acre and soil, water, and plant conservation.

Some of the nonarable lands of the West are publicly owned. These are used along with privately owned lands for livestock production. Many of the publicly owned lands have multiple use. They have important watershed values, are grazed by livestock, and support large numbers of game animals. Lands with multiple use offer some problems in forage management, especially when they are grazed by both game and livestock.

The views expressed in this paper are based on field experience with many farmers and ranchers in soil conservation districts and on the results of research work. It is clearly evident that production of forage crops in the West can be greatly increased through management. Management directed to greater and more consistent production includes managing the land, the crop, the livestock, and, in the case of irrigated land, the water.

HAY

Musgrave and Kennedy (48)[1] in their review of the literature point out that in processing forage crops for storage, and during the storage period, more losses of feeding value occur than are gained by forage-crop improvement and better cultural practices. They regard the preservation and storage of high quality roughage as the most serious problem in the field of forage-crop improvement and management.

Hay is grown on 7,390,000 acres of cultivated land in the West, and "wild" hay is harvested from 2,619,000 acres of native meadows. Hay crops on cultivated land serve many purposes. Among the more important are conserving soil and water, maintaining and improving soil structure and fertility, and providing roughage for livestock feeding. There has been an increasing appreciation of the role of adequate feed reserves toward implementing better pasture and range management. Hence, improvement in the culture and management of grasses and legumes used for hay has many indirect agronomic benefits in addition to providing forage.

Many forage crops are used for silage, especially in areas when the making of high quality hay is hindered by wet weather. The principles used in making silage in the West are the same as those reviewed by Musgrave and Kennedy (48). There has been a rapid increase in the use of pit silos, and they are proving successful. Grass silage is growing in popularity.

Alfalfa is the principal hay crop of the West. More alfalfa is produced than all other hays combined. The data from the 1950 Census of Agriculture show that alfalfa was harvested from 43 percent of the 10,009,000 acres used for hay in the 11 Western States. Because of high yields per acre, almost 65 percent of the tonnage of all hay was alfalfa.

Management of alfalfa for greater production includes practices that increase yield per acre, improve quality, and reduce losses common to harvesting, storage, and feeding.

Varietal adaptation has been the subject of much research, and improved varieties of alfalfa have been developed for each major producing area. Yield and resistance to disease, winterkilling, and insects have been the object of this work. The major results from using improved varieties have been increased production and the maintenance of good stands during the time that

[1] Underlined numbers in parentheses refer to Bibliography.

the crop remains on the land in a rotation. However, the use of improved varieties grown from certified seed is still far from a general practice in many communities. The total production of hay will increase when more use is made of certified seed of alfalfa varieties.

Phosphate fertilizers have increased the yields of alfalfa on irrigated lands in most areas. The average increment per pound of P_2O_5 exceeds 50 pounds of dry matter, and the optimum application is 60 to 70 pounds of P_2O_5 annually. Where alfalfa responds to phosphate fertilizers the hay often shows an increase in percentage of phosphorus (55, 60, 61). In subhumid areas sulphur often increases the yield of alfalfa hay, especially if the soils are derived from basalt. Responses from other fertilizers are negligible in the major alfalfa-producing sections. There are instances where growers have made continuous use of heavy applications of manure to irrigated alfalfa fields. Exceptionally high yields have been maintained for as much as 10 years with no measurable reduction in stand. Such results suggest that soil management may have a greater influence on production and susceptibility to disease than is often recognized.

Many studies have been made to determine the consumptive use of irrigation water by alfalfa. Although the values differ by location and with season, they are sufficiently precise to make it possible to design irrigation systems and schedules toward greater efficiency of irrigation. The data are reviewed by Blaney and Criddle (6) and Myers and Shockley (47). Efficiency of irrigation is important in water conservation, soil management, and the economy of hay production. It has been the experience of technicians working with farmers that the use of water can be materially decreased without decreasing the yields of alfalfa hay. Proper land preparation, adequate farm-irrigation structures, and skill in the handling of water by the irrigator have greatly increased irrigation efficiency. The results of work conducted by Scofield (quoted by Blaney and Criddle (6)) show that the water requirement of alfalfa is decreased with an increase in soil fertility. More work of this kind is needed.

In some parts of the West rainy weather at the time that alfalfa is usually cut for hay makes curing difficult. It has long been a common belief that the cutting of alfalfa prior to a stage between 1/10 and 1/4 bloom had adverse effects on the vigor of the plant and on yield per acre. According to the work of Jacobs (33), frequent clippings for 2 successive years at relatively immature stages had less effect on yield and much less residual influence on stand and yield in the third season than has been the case in other parts of the country. Within limits, therefore, it appears that the date of cutting alfalfa for hay can be advanced or retarded into more favorable weather without damage to the stand.

Skinner's (56) studies point out that about 10 percent of the hay crop is lost in harvesting, storing, and feeding. The part lost is the fraction that contributes most to the

A good supply of hay aids management of range and pasture. (Lamoille Soil Conservation District, Nev.)

A good crop of alfalfa-grass hay provides high-quality roughage and carries the animals through winter cold and rainless summers when range and pasture are short. (Portneuf Soil Conservation District, Bannock, Idaho.)

quality of the hay. If this loss were average for the 11 Western States, more than 1 million tons of feed would be wasted. At least some of this loss in quantity and in quality could be saved by selecting methods of handling suited to the operations on the farm or ranch. Skinner points out several ways by which these savings can be made.

Machines for handling the hay crop have been greatly improved. They influence efficiency of operation, especially on large fields, and this is reflected in the quality of the hay (58). Even so, much of the hay that is fed or marketed could be of higher quality. This is especially true with alfalfa on irrigated land in the arid parts of the West where weather is favorable to a quality product. Closer attention to selling hay on grade with a price differential would undoubtedly bring about a more general consciousness of quality.

Mechanical means for drying hay are used to some extent west of the Cascade Mountains where dew and late spring rains make field curing difficult. Mow-type or silo-type driers are used to a limited extent to produce a better quality hay than could be obtained with field curing (39).

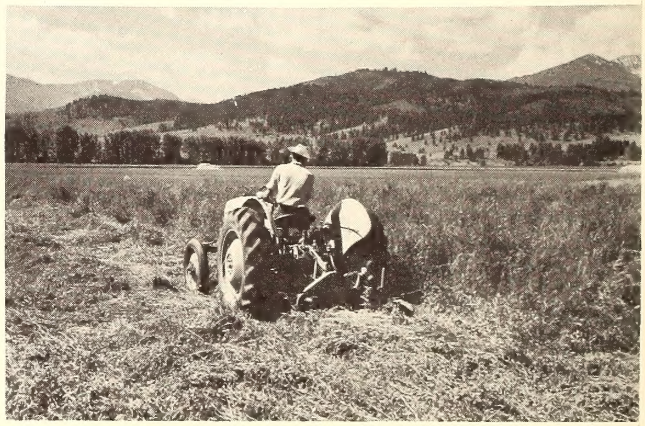
Mixtures of grasses with alfalfa for hay and soil improvement were a result of the conservation movement. The mixtures were obviously better than alfalfa alone in controlling runoff and erosion on sloping lands. Woods et al. (62) showed that mixtures produced more fibrous root material for improving soil structure. When mixtures were grown under irrigation and plowed, irrigation water was easier to handle. Tileston[2] has shown that grass increases the intake rate of water by soil and greatly improves lateral movement of water. Jacobs (32) found that grasses prevented the invasion of cheatgrass into alfalfa fields.

Objections were raised that grass with alfalfa might decrease yields and lower the sale value of hay. Keith et al. (36) have shown that good hay containing as much as 30-percent grass by weight was equal to alfalfa in fattening lambs. The advantages of mixtures are obvious, but public acceptance is general only in some areas. Attention should be given to grading and marketing alfalfa-tame grass mixtures so that they are not penalized on price.

One of the first difficulties in planting mixtures of grass with alfalfa was maintaining the desired percentage of grass. The difficulty was competition in the seedling stage. This was solved by planting grass and alfalfa in alternate drill rows. By this means the percentage of grass was obtained and maintained. The optimum percentage for good hay, root production, and yield was 30 to 35 percent by weight grass. When this percentage of grass was obtained it eliminated bloat in sheep and steers that were fed chopped hay as part of the finishing ration at the Eastern Oregon Livestock Branch Experiment Station.

Aftermath grazing of alfalfa fields in the fall of the year is a widespread practice in the West, especially in the range livestock area. Many fieldworkers believe that this practice is detrimental to stands and results in reduced yields of hay the following season. The work of Jacobs (33) on this point verified the observations made in the field. The influence of removing top growth after September 1 in central Washington was greatest on the first cutting the succeeding year but was reflected in all three cuttings. Yearly repetition of this practice may prove to have a cumulative detrimental effect on both stand and yield.

Meadow hay was harvested in 1949 from more than 2,600,000 acres in the 11 Western States. Native grasses, legumes, sedges, rushes, and forbs are the plants on these meadows. Many meadows are irrigated, but the yield per acre is low and the quality of hay is often poor. There is



More than 5 tons of alfalfa-smooth brome hay were obtained from 2 cutting in this Oregon hayfield. Alfalfa-tame grass mixtures produce high yields, prevent bloat when fed, are free from weeds and weedy grasses, and are easy to cure and handle. (Baker Valley Soil Conservation District.)

[2] Unpublished data of Agricultural Research Service.

evidence that many meadows have declined in yield and in quality of feed. These meadows are found throughout the range area, and the hay harvested from them is vital to livestock production and to good range forage management. Recent research and the work of several ranchers have shown that yield and quality of native meadow hay can be improved.

Cornelius and Graham (11) report an increase of more than 200 percent in yield of forage after control of buttercup and other weeds on mountain meadows by spraying with 2, 4-D. Cooper and Sawyer (10) applied N and P_2O_5 at different rates to native meadows in eastern Oregon that were irrigated from floodwaters in the early spring. Nitrogen gave an average increment of slightly more than 30 pounds in yield of hay. Responses to P_2O_5 depended on the presence of native clovers, but the maximum increment for P_2O_5 was about 29 pounds of hay at the 40-pound rate.

Work with irrigated mountain meadows in Colorado is showing that controlled intermittent irrigation gave significant increases in pounds of protein in the harvested hay. When combined with a two-cut system of harvesting, the yield of protein per acre was still greater (46, 53). The figures given for water used per ton of hay by the continuous and intermittent methods of irrigation--136 inches and 2.9 inches per ton of hay--are of interest to water conservationists even though the meadows studied may have been subirrigated. The interaction of cutting and irrigation methods and nitrogen applications on yield of protein per acre in the hay at high elevation will be watched with interest. Proper management methods will not only increase the production of forage on these meadows but, because of more stored feed, should facilitate range management toward higher and more stable grazing capacity.

PASTURE

Animals graze the forage from two principal classes of pasture in the West: pasture on cultivated land and native forage range. The pastures on cultivated land are irrigated in arid and semiarid areas, and there is a substantial increase in the use of supplemental irrigation in subhumid areas. About 3,804,000 acres of pasture in the 11 Western States were irrigated in 1949. In addition, 5,622,000 acres were cropland used for pasture but not irrigated. Besides this total of 9,426,000 acres of cropland used for pasture, there were 552,242,000 acres of native forage range.

Pastures on cultivated land.--The pastures on cultivated land vary greatly in grazing capacity. The differences are due to climate, soil, and management. Highest production is obtained from irrigated pastures on good land, while unirrigated pastures in semiarid areas are usually low in production. Most of the pastures on cultivated land are rotation pastures and as such make valuable contributions to soil management in

An intensive system of rotation grazing is followed on this well-managed Utah pasture. Alfalfa-grass mixtures produce high yields of good-quality pasture on good soils if they are properly irrigated and fertilized. (Timpanogos Soil Conservation District.)

addition to providing feed for livestock.

It has been estimated that forage production on pastures could be increased as much as 100 percent, and experience in the field bears out this estimate. Production is increased in almost all locations by the selection of high producing species and mixtures and by improved systems of grazing. When continuous or seasonal irrigation can be used it is the greatest single factor for increasing yield. The application of fertilizers increases production in subhumid and irrigated areas.

Irrigated pastures.--According to the 1950 U. S. Census of Agriculture, slightly more than 40 percent of the pastures on cultivated land were irrigated. Fifty-one percent of the irrigated pasture acreage was classed as "tame" and the rest as "wild" pasture consisting of native grasses. Methods of management for improving production on both of these kinds of pasture have been worked out during the past 20 years by action and research agencies. They are based on a knowledge of the ecology of the pasture community and the physiology of the species in the mixture.

The aim of management on irrigated pastures is high production of TDN per acre and uniform production during the grazing season. Fixed costs on irrigated tame pasture are high, and, as shown by Hyer and Becker (31), net profits per acre can be increased by increasing the production of TDN per acre. Irrigated pastures in western Oregon producing less than 3,500 pounds of TDN did so at a cost of $23.70 per 1,000 pounds of TDN, while those producing 7,000 pounds cost only $9.20. The actual per acre difference in cost between the low and high yielding pastures was only $10.00, or about 16 percent. Gorton (17) obtained similar results and pointed out that the cost of maintaining an acre of irrigated pasture was largely made up of items that do not fluctuate with yield. Hence, yield per acre was the key to low cost pasture management under conditions of relatively high fixed costs and in his survey was achieved by the use of higher yielding kinds of forage.

The trend in the West has been toward relatively simple pasture mixtures. Recommended mixtures seldom contain more than two perennial broad-leaved grasses and one legume. The recommendations often specify improved varieties. Experience has shown that simple mixtures are easier to manage, and Chapin, et al.(8) found that complex mixtures tend to become simple in a few years, even with good management. The intensive study of irrigated pasture mixtures by Bateman, et al.(3) on good soil and with good grazing management shows that higher production can be obtained from moderately complex mixtures of broad-leaved, long-lived perennial grasses and several legumes. Therefore, as improved grazing management becomes more common, it would seem possible to maintain slightly higher levels of production with more complex mixtures, at least on good land.

Many grasses and legumes are needed for pasture mixtures in an area as large as the West and as diverse in climate, soil, and available irrigation water. The typical ones were summarized by Hafenrichter (19). Most of the grasses are cool-season species, except in the extreme southern part of the area where warm-season species can be used, but Dotzenko and Wilson (13) indicate that better grasses are needed for this area. Ladino and white clover have been the principal legumes, but recent research is showing that better yields are possible when alfalfa or trefoil are used (Schudel [3], Kopland, et al. (40), Bateman, et al. (3), Hagan and Peterson (20), and Heinemann and Van Keuren (23)).

An important objective of compounding mixtures is to obtain one that is as equally satisfactory for hay or silage as for pasture. The reason is that herbage production on irrigated pastures, despite good cultural and grazing management, is still far from uniform during the growing season. Seldom is it practical to vary livestock numbers during the season; hence, carrying over the excess feed as hay or silage is common practice. The use of supplemental or seasonal pastures is very limited.

Another aim in compounding mixtures is to obtain a proper balance between grasses and legumes. Livestock operators are fearful of bloat when the percentage of legume approaches 50 percent. However, management of established stands has been shown to be more important in maintaining a desired composition than is the seed mixture.

Still another general trend in compounding mixtures has been the omission of common rapid-developing but short-lived grasses. It has been shown that such grasses reduce the ultimate stand of the more productive but slower-developing species and often the percentage of legume in the mixtures (8).

There has been a gradual spread of better land preparation for pasture seedings. Good seedbeds and precision drilling are more general than they were 20 years ago. Land intended for pasture is releveled to facilitate irrigation and obtain better distribution of water.

Grain crops are still used to establish pastures on irrigated land and in subhumid areas. This practice is responsible for poor establishment on

Electric fences divide this irrigated pasture into $\frac{1}{2}$-acre units. Orchardgrass, Alta fescue, and ladino clover are the grasses on the pasture. Such pastures can carry more than 3 high-producing dairy cows per acre. (Willamette Valley, Oreg.)

On this Idaho ranch herds are driven from one seeded dry-land pasture to another to provide rotation grazing. (Caribou Soil Conservation District.)

many farms. Some research workers have used this method with success on good fertile soil with irrigation, but they have been careful to manage the water to favor the forage. Experience among farmers, generally, indicates that the grain crop usually receives major attention at the expense of the pasture seeding. A growing practice is to stubble-in the pasture seeding after the grain crop has been harvested. The seeding is made as early as possible after midsummer so the plants, especially the legumes, are well established before the irrigation water is turned off or before freezing weather sets in.

Water and labor for irrigating are recognized expenses in pasture production. Efficiency in the use and application of water can maintain high production and reduce costs per acre. Only a limited amount of experimental work has been done on managing water on irrigated pastures. The total amount of water needed per season for irrigated pastures in the West ranges from 30 to 80 inches. Climate, primarily temperature, is the factor responsible for this wide spread in water used. Even within one State, Myers and Shockley (47) show that the average consumptive use of water by pastures varies widely; for example, during the month of July for 44 locations in Idaho it ranges from 5.22 to 6.49 inches. Seasonal differences in temperature at any location also influence consumptive use.

Frequency of irrigation may affect pasture yield but more often it influences botanical composition. Soils and botanical composition are the most important factors in determining frequency of irrigation (21).

The available moisture-holding capacity ranges from 0.75 to 1.0 inch per foot in sands and loamy sand to 1.6 and 2.5 inches per foot with fine-textured silty clays and clay.

A general rule based largely on field measurements is that forage crops should be irrigated when about half of the available moisture in the root zone has been used (Myers and Shockley (47)). This rule provides a safety factor of about 1 inch of moisture in the root zone. A general guide for field use is to bring the moisture back to field capacity when the available moisture has been used from the top one-fourth of the root zone. When plants with different root-growth characteristics are used in the pasture mixture, it is necessary to irrigate to satisfy the requirements of those with the shallowest roots. If pastures are irrigated according to this rule, some changes in apportionment of water use within many irrigation districts will be necessary. If this is not possible, the choice of mixture will need to be made on the basis of apportionment.

The work of Hagan and Peterson (20) shows the difference in the use of water from different depths of soil by pasture mixtures that contained Ladino clover, broadleaf trefoil, and alfalfa. Ladino clover extracted water to a depth of 4 feet, trefoil to 6 feet, and alfalfa to 8 feet. Extraction in the top 2 feet was most rapid by Ladino clover, intermediate by trefoil, and least with alfalfa. Managing the pasture mixture by harvesting at 2-, 3-, 4-, and 5-week intervals did not influence consumptive use of water, even though the yield due to regrowth intervals ranged from 2.41 to 6.58 tons per acre. This result is of considerable importance in the West where water supplies are often limited and rates are frequently high because the yield of pasture forage can be increased by controlling the grazing interval without increasing the use of water.

The work of Keller (37) offers another approach to the efficiency in the use of water. He was able to show that genotypes of orchardgrass differed from 670 to 1,082 in water requirement. This work, along with the work of Hagan and Peterson (20), allows the suggestion that studies on the extraction of water from the soil column by grasses and breeding for more desirable root systems would be profitable undertakings.

There are reports that indicate an interaction exists between water requirement and fertilizers. Should this be established, greater efficiency in the use of water would result. More study in this field is needed in the West.

Many studies are in progress to determine the effects of N, P, and K when applied at different levels, singly and in combination, to irrigated pastures. Manure is used in comparison with commercial fertilizers in some trials. Lime is often added in the area west of the Cascade Mountains in Oregon and Washington. Many of the results are measured with clippings, but some trials are conducted with grazing animals. Results with fertilizers vary widely and are influenced by soils, climate, and management practices.

Most irrigated pastures show responses to phosphate. Increased yields are attributed to greater production from the legume portion of the mixture. Annual applications of about 60 to 70 pounds of available P_2O_5 appear to be optimum. However, results vary widely and appear to be affected by soils and the ratio of legume:grass in

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[3] Schudel, H. L., Oreg. Expt. Sta. [Private communication].

the mixture. When recorded data are computed to obtain the increment in yield per pound of P_2O_5 applied, the values range from as little as 4 to as much as 173 pounds of dry matter. The land operator needs to know the increment he can expect before making applications of this fertilizer. There is no general trend in the results to show that P_2O_5 affects the quality of feed except that attributable to the greater yield of legumes. There are indications that the results from using P_2O_5 are influenced by other fertilizer elements on several soils.

Research workers do not agree on the use of inorganic nitrogen on irrigated grass-legume pastures. Review of many experimental results and of results obtained on farms indicates that the response to nitrogen depends on several other factors, of which soils, climate, seasons, application of water, and the use of other fertilizer elements are the more important.

A general experience is that the use of large amounts of inorganic nitrogen may decrease the percentage of legume in the mixture. This, in turn, nullifies the amount of nitrogen that can be obtained by symbiotic fixation. There are exceptions to the reduction of clover when inorganic nitrogen is used, both in experimental results (Dotzenko and Wilson (13) and Jacobs (35)) and on farms. Apparently the fertility level of the soil influences the results. There is general agreement that nitrogen stimulates the grass fraction of the mixture, and this reaction is used by many operators to maintain a grass:legume ratio that is less likely to incur bloat. Observation of many grass:Ladino pastures in the North indicates that other factors may be responsible for reduction in the legume fraction. Slugs, for example, are often present in large numbers and may reduce the Ladino stands during prolonged cool spring weather.

The increase in production per pound of nitrogen applied ranges from 0 to 80 pounds. It is apparently influenced by the same factors that affect response to P_2O_5. On low fertility level soils the response is directly proportional to the amount of nitrogen applied, up to 360 pounds per acre. The results are different on fertile soils. Other things being equal, the operator will use nitrogen if the increment provides 1 cow-day of grazing or more. When nitrogen is used there is general agreement that split applications of not less than 20 pounds per acre give best results and that the applications should be made just after the pasture is grazed in each rotation cycle. [4]

A most interesting result is obtained when manure is applied to irrigated pastures. In most cases it is supplemented with phosphate fertilizer. When manure is the source of nitrogen the same increment in production is obtained as with inorganic nitrogen, but with only moderate reduction in the percentage of legume in the stand. There are no reported experiments comparing different rates of inorganic nitrogen and similar rates of nitrogen from manure. In one trial now in progress manure is being compared with 120 pounds of inorganic nitrogen, and phosphate is applied with both sources of nitrogen. In this case the reduction in percentage of clover is far less on the manured plots. The recommendation is often made that it is better to use manure on cash crops and commercial fertilizers on pasture. One wonders if this is well-considered advice for a dairy or livestock ranch in the light of recent research on pastures.

Many results from the study of fertilizers are based on yields from clippings. It is common in the profession to hear that clipping may be a poor estimate of results that are obtained by grazing. This comment refers primarily to the difference in method of harvest. However, one wonders why the difference due to fertility has been overlooked. A rather significant amount of N and K and some P is added to the land by animals when the grazing capacity of the pasture is, for example, 2 animal units per acre during a 6-month grazing season. True, these elements are not uniformly distributed over the pasture, but some correction in design of trials measured by clippings seems advisable if conclusions are to have application on farms. This was brought forcibly to our attention in a factoral test using N, P, and K on clipped irrigated mixtures on soil where responses to K were never before obtained (2). During the third season a pronounced response to K was obtained. The plots were giving high forage yields, but all the vegetation was removed. The deficiency observed here could have been made up easily by the amount of K in the droppings from grazing animals.

There is no general response by pastures to K_2O in the West, except that it is standard practice to recommend its use on soils high in organic matter, especially if peat is encountered. Some preliminary studies in progress that are supplemented by field trials indicate response to K_2O when high levels of N and P_2O_5 are used.

The acreage of pasture in the West that is reported to be treated with N, P_2O_5, and K_2O is

Supplemental dryland pastures make good grazing management easier. This Manchar brome-Tualatin oatgrass-alfalfa pasture carries a beef herd in late summer after the native range forage is no longer green. (Caribou Soil Conservation District, Idaho.)

4 Johnson, R. F., Pasture fertilization trials. Idaho Agr. Expt. Sta. [Private Communication].

still a small percentage of the total planted acreage (49). Even so, it is greater in percentage than that reported from other sections of the country except the Northeastern States. Relatively more P_2O_5 is used than N and K_2O. We can probably look toward the use of more fertilizer as specific data indicate profitable returns and as operators adopt other improved pasture-management practices.

The trend is definitely toward rotation grazing of irrigated pastures in the West. There is an encouragingly wide acknowledgment among farmers of greater yield of meat or milk by rotational grazing as compared with continuous grazing. Three- and four-paddock systems are common, but large operators and several operators of good herds on family-size farms are tending toward strip grazing. A few large operators are using forage harvesters and lot feeding. The intensity of the method used seems to depend on the capital investment the operator can make. Most operators can afford electric fences to effect rotation grazing.

The results reported by Chapin, et al. (8) for nonirrigated pastures west of the Cascades showed that yields were increased 28 percent when a 3-paddock system was used and compared to continuous use. On another soil type, but under similar climatic conditions, Hodgson et al. (24) obtained only 9.14 percent increase in favor of the rotational-grazing system. This small difference made them question the feasibility of the rotation system. Hence, in one important dairy area there appears to be an interaction between soil type or fertility level or both and system of grazing.

The work of Peterson and Hagan (50) using clippings to measure the effect of different regrowth periods on four mixtures on irrigated land shows that extending the regrowth interval from 2 to 5 weeks increased average forage production for the season by 92 percent. However, there were several important interactions of interest to pasture managers. The four mixtures originally differed only in the legume used. In all cases the legume portion of the mixture increased with the length of the regrowth interval. The difference was greatest with alfalfa, least with Ladino clover, and intermediate with trefoil. The percentage of grasses decreased in all cases to 20 percent or less when 5 weeks' regrowth was used, but the decrease was least when Ladino clover was used and most when alfalfa was the legume. The use of fertilizers was not reported.

These data give some indication of the effect of management on botanical composition, verifying results observed on farms.

Schudel[5] in western Oregon obtained a 46-percent increase in production with each of two pasture mixtures by increasing the regrowth period from 2 weeks to 5 weeks. The longer regrowth period resulted in a decrease in the percentage of the legume in the mixture containing Ladino clover and an increase in the mixture containing trefoil. His work considered an added management factor: height of clipping. Ladino clover is favored with close clipping, especially with long regrowth intervals and trefoil with high clippings.

Pastures on saline and alkali soils.--Nearly half, or 1,875,000 acres, of the irrigated pastures in the 11 Western States are "wild;" that is, they contain only native forage species. Some of these pastures receive only intermittent or seasonal irrigation. Rather large areas are on saline or alkali soils. The yield of "wild" pastures is lower than the yield of "tame" pastures. Nevertheless, they are an important source of feed in livestock-producing areas.

Many pastures on saline soils have been reclaimed. When soil surveys and other determinations show that drainage can be provided, the salts can be leached from the soils and the more salt-tolerant tame grasses and legumes can be grown. Examples of such plants are Goars fescue and narrowleaf trefoil. With proper irrigation and the use of N and P_2O_5 fertilizers, yields have been increased many times over those produced by "wild" forage plants.

Rather large acreages of land that is or can be irrigated are on alkali soils. These lands are difficult to reclaim by leaching and the use of soil amendments such as gypsum with organic matter. However, if the land is prepared so that irrigation water can be properly applied and the structure of the surface soil is sufficiently improved with amendments to allow germination, alkali-tolerant pasture plants can be used. Tall wheatgrass (Agropyron elongatum) has been very successful. Special care must be given to this grass during a 6-week establishment period. Frequent light irrigation is required, and best results are obtained when deep-furrow-press drills are used for seeding. This method results in the salts moving to the top of the ridges between the furrow and gives the seedlings an opportunity to become established. Although tall and relatively coarse by tame pasture standards, tall wheatgrass is exceptionally productive when grazing is properly managed. Yields vary but have been as high as 6 animal-unit months per acre at 50-percent utilization.

Pastures on nonirrigated land are found primarily in subhumid areas. Upland pastures west of the Cascade Mountains in the Pacific Northwest have been studied by Austenson et al. (2) and Chapin et al. (8). Management for nonirrigated pastures in the intermountain zone of the Northwest has been reported by Galgan et al. (15). Chapin et al. (8) studied 20 mixtures under 2 systems of harvest for 4 seasons. The best mixtures were simple and consisted of a broad-leaved bunchgrass and one persistent legume. Akaroa orchardgrass or Alta fescue combined with White Dutch clover or Tallarook subterranean clover gave the best yields. Ryegrass always reduced the percentage of clover regardless of method of harvest. Rotational use gave 28 percent more forage than continuous use. Austenson et al. (2) showed that response to P_2O_5 was consistently high, that response to N de-

[5] See footnote 3.

pended on soil type but did not interact with applications of P_2O_5 or K_2O, and that the pastures responded to K_2O only after all the clippings were removed for 3 years. There was no response to any minor element.

Galgan et al. (16) compared Alta fescue and intermediate wheatgrass planted alone and with alfalfa when grazed with steers in eastern Washington. Intermediate wheatgrass treated with 100 pounds of N provided as much grazing as did an intermediate wheatgrass-alfalfa mixture. Both pastures produced more than 230 pounds of beef per acre. Yields with this new grass were much greater than with Alta fescue. An earlier study at this same location showed that alfalfa-grass mixtures provided an average grazing capacity of 4.28 animal-unit months per acre, while grass alone but not fertilized provided an average of only 1.62 animal-unit months (14). In addition, the mixtures gave a slightly longer grazing season. At 70- to 80-percent utilization there was little difference in grazing capacity between mixtures containing smooth brome, crested wheatgrass, or both with alfalfa. All mixtures produced an average of more than 220 pounds of beef per acre. The superiority of mixtures over alfalfa alone in this area for soil protection and improvement has already been mentioned; hence, such pastures are important in conservation work.

Many acres of alfalfa-grass mixtures on nonirrigated land are grazed in the intermountain area of the West where rainfall is at least 15 inches. The chief difficulty with such pastures is the relatively short grazing season caused by rainless summers. Green feed for grazing in the Northwest, for example, is provided only during late April, May, and June. After July 1, supplements must be fed if cattle are to maintain gains. The introduction of late maturing grasses, such as intermediate wheatgrass, that are compatible with alfalfa has resulted in better yields and some extension of the green-feed period. Some supplemental pastures such as first-year grass-sweetclover mixtures can be grazed after midsummer.

RANGE

The total area of land in the 11 Western States is slightly more than 753,368,000 acres. Of this amount 73 percent is grazed and 46 percent of the grazed acreage is in private ownership. It is estimated that the grazing lands are producing about 50 percent as much forage as they did 75 years ago and that production can be restored through management to slightly more than 75 percent of the yield under virgin conditions. This increase would provide for more than 5,000,000 animal units and still maintain the range in good condition.

Management of grazing lands to improve and maintain forage production falls into three categories: forage-management practices, enabling practices, and facilitating or speedup practices.

Bunchgrass range in EXCELLENT condition. At least 90 percent of the forage is provided by native perennial grasses. No weedy annual grasses or brush occur. There is a good understory of Sandberg bluegrass between the climax wheatgrasses and Idaho fescue. This range provides more than 1 animal-unit-month of grazing per acre under good management.

Much progress has been made in the past 20 years in range-forage management. Fundamental studies in the ecology of plant communities and in the physiology of range species have given direction to management. Simplification of criteria for determining range condition and trend has made it possible for the user of the range to detect signs of improvement or deterioration in the vegetation.

Range condition is based on plant succession and expresses the present state of the vegetation in relation to climax conditions for the site. The climax association is regarded as optimum in yield and quality. Range trend as determined by the existing vegetation indicates whether climax species, subclimax species, or invaders are increasing under existing management.

Range in FAIR condition. Only 80 percent of the forage is provided by native perennial grasses, understory grasses are absent, and weedy annual grasses and brush have invaded the stand. Such range provides about two-thirds animal-unit-month of grazing per acre. It can be improved with good grass management practices.

Range in POOR condition. Native perennial grasses make up less than 10 percent of the stand; 80 percent of the forage is weedy annual grass and 10 percent is forbs. About 6 to 8 acres are required to provide 1 animal-unit-month of grazing, and then only for a short time in the early spring. Such ranges should be reseeded.

The aim of range-forage management is to increase the density of desirable forage species and to decrease undesirable grasses, forbs, and shrubs.

Standards have been established for range readiness when grazing can begin without injury to the plants or to the soil. Grazing prior to readiness results in lower yields, reduction in the density of desirable species, invasion of weeds and brush, and in soil compaction. Increasing the amount of supplemental feeds, especially hay, makes it possible to avoid grazing the range before readiness and still maintain livestock in good condition. The highly variable climate of the West makes it necessary to provide feed reserves for more than one season.

Range plants have critical periods during the growing period when removal of the herbage has debilitating effects, especially when the plants are grazed then for several succeeding years. Perennial bunchgrasses are more easily damaged than rhizomatous species. Stoddart (59) reviewed the work in this field and showed that damage to bluebunch wheatgrass from herbage removal was inversely proportionate to the amount of herbage exposed to sunlight during the warm season as attained by (1) less close clipping, (2) clipping early enough to allow regrowth, or (3) clipping late enough to allow food storage before herbage was removed. Hanson and Stoddart (22) showed that herbage removal by heavy grazing (use) decreased the production and depth of roots. Crider's (12) recent studies on clipping and growth of grass roots support this work. More studies of this kind on other perennials are needed. Each species is known, from field experience, to have a season of use when herbage can be harvested with minimum damage. The work of McGinnies and Arnold (44) shows that climax species such as those found on range in good condition have a lower water requirement than species found on range in poor condition. This is important to the ranch operator and to water conservation in the West.

Two practices, corollary to proper season of use, have been established to prevent damage to the principal forage species on the range.

Rotation-deferred grazing provides that the range is divided into three or more areas of approximately equal grazing capacity, and these are grazed in rotation but not at the same time in successive years. This practice has proved beneficial on many ranches in the bunchgrass association and has resulted in improvement in range condition and increase in yield of forage. A typical example is that after 5 years of using a rotation-deferred system on Pacific bunchgrass range the same amount of beef was produced with only half as large a breeding herd. Range forage improved 40 percent, and runoff and soil erosion were completely checked. Work in the area where summer-growing sod grasses are dominant has left some doubt whether or not the system is feasible. Sampson (54) reviewed the literature, and the results of work by Hubbard (26), Hyder and Sawyer (30), Rogler (52), McIlvain and Savage (42), and Fisher and Marion (15) allow the conclusion that the rotation-deferred system is more useful in the area where bunchgrass associations predominate. It is applied to bunchgrass range when it must be grazed during the entire growing season or during the entire grazing season. Even on winter ranges the results of work by Hutchins and Stewart (29) lead them to advocate rotation-deferred grazing.

Degree of utilization is the second management method used to maintain or improve range condition and yield of forage. Studies that compare light, moderate, and heavy use show that moderate use results in maintaining the range in good condition and allows the optimum production of animal products (9, 29, 63). Moderate use on spring, summer, or fall ranges is usually regarded as harvesting an average of about 50 percent of the current season's growth of the key species. For ranges used only during the winter, moderate use can be somewhat higher (29). Moderate use has decreased the degree of fluctuation in yield of forage among years on ranges in arid areas. Cook et al. (9) and Hutchins and Stewart (29) show that as the degree of utilization increased, the content of the more desirable nutrients and their digestibility was decidedly lowered.

Enabling practices have as their purpose the uniform utilization of forage. They include fencing, herding, salting, and the development of stock water. All of them aid in distributing the livestock more uniformly over the range area. A very large number of stock ponds have been developed in the last 20 years.

Three speedup practices increase forage production on ranges. They are relatively costly and results depend on several interacting factors.

Removal of undesirable invading forbs and shrubs by chemical or mechanical means or by fire releases desirable forage species. Cornelius and Graham (11) showed that forage production on mountain meadows was tripled when buttercup and other weeds were killed with 2,4-D. Many trials with herbicides on sagebrush and other woody species show similar improvement, but results have been erratic due to factors not yet understood. The removal of shrubs from semiarid or desert ranges conserves moisture because the woody species have a higher water requirement than grasses as was shown by McGinnies and Arnold (44).

Fire, when properly used, is successful in removing nonsprouting shrubs from western rangelands. Increases in yield of forage from 40 to 100 percent were reported by Blaisdell (7) as a result of removing big sagebrush with fire. On steep lands on light-textured soils, water and wind erosion may follow fires. Range grasses differ in the degree to which they may be injured by fire. Because of possible damage to the soil and to the remaining forage grasses, care must be taken when using controlled burning to remove undesirable shrubs. Shrubs that sprout from the crown are not eliminated by a single fire, as shown by Biswell (5) and Love and Jones (41). Removing sagebrush by mechanical methods such as beaters, drags, and mowers releases good forage species, but this method has limited application in the West with present-day machinery, especially on steep lands and on rocky sites.

Fertilizers can be used on some ranges to increase forage production and to facilitate management. Hoglund et al. (25) obtained an increase of 3,000 pounds of air-dry forage per acre by applying 200 pounds of ammonium-phosphate-sulfate (16-20-0) to annual forage range in California without measurable change in botanical composition. In addition, and equally important, range readiness was advanced an average of 6 weeks. No increases were obtained by the use of P_2O_5 alone or by the use of K_2O, Ca, or S. Bentley and Green (4) obtained an average increase of 1,000 pounds in forage yield on the same range type by applying 60 pounds of S. The soil in this case was of granitic origin, and increases were due to the stimulation of the legumes in the stand. Retzer (51) applied 14 fertilizers, including minor elements, to 7 soils growing native short grass and mixed prairies in Colorado. No important increases in yield were obtained. Cooper and Sawyer (10) obtained an average increment of 34 pounds of air-dry forage for each pound of nitrogen applied to native flood meadows in eastern Oregon and an increment of 28.8 pounds for each pound of P_2O_5 up to 40 pounds per acre when native clovers were present. Hence, soil type may be a factor in the results obtained with fertilizers.

Fertilizers, when successful, are a supplement to forage management practices on western ranges. As shown by Hoglund et al. (25), Bentley and Green (4), and Cooper and Sawyer (10), fertilizers are used on selected sites on the range and these sites, when properly used, can implement the institution of forage management practices to improve condition on other parts of the range. When fertilizers are used on part of the range without a plan of management for the entire ranch, they may do more harm than good.

Range reseeding has received widespread attention in the West, especially during the past 20 years. Emphasis was placed on returning severely eroded grainlands in the arid areas to grass and on seeding badly depleted publicly owned rangelands. It was estimated that slightly more than 90 million acres should be seeded, of which 57 million acres were privately owned and the rest was in public ownership. Recent estimates show that about 45 percent of the privately owned lands and 14 percent of the public lands that could be reseeded have been planted.

In the beginning it was thought that reseeding of rangelands should be done as cheaply and as rapidly as possible. Therefore, the results of early efforts were erratic but sufficiently encouraging, despite stringent climatic conditions, to warrant continuing effort.

Coincident with large-scale operations, much research work was conducted to determine what, how, when, and where to seed. The results of this work and of extensive operations have clarified objectives and procedures (1, 18, 27, 28, 45, 57).

The principal results of reseeding research and experience are: (1) That the reseeded area must fit into the grazing-management plan for the ranch or the range unit. Little advantage and possible harm to range condition came from seeding a small area within a large grazing unit to species quite unlike the native forages in season of use or quality. (2) That the better sites, especially with respect to soil, had the greatest potential for increasing grazing capacity of the range area and could best be fitted into the management plan. (3) That every possible effort should be made to prepare a good seedbed that allowed precision seeding. On arid lands and on rough topography, often with sandy or stony soils, this was no easy matter. Many special machines have been constructed and subjected to engineering research to make them suitable for

A seeding of Whitmar wheatgrass in Washington. This is the first of many seedings made on this ranch to convert 50,000 acres subject to wind erosion to grass. (West Benton Soil Conservation District.)

A good seeding of Whitmar wheatgrass on range from which sagebrush was removed by controlled burning. Such reseeded ranges when fitted into the grazing-management plan for the ranch can be the key to increased forage production. (Wood River Soil Conservation District, Idaho.)

land preparation and seeding. This advance has done much to reduce unit costs, to effectively remove competition, and to reduce the hazards to establishment imposed by limiting and erratic climatic conditions. (4) That a sizeable mass of information is at hand on what and when to seed. A vast number of common forage species and an even greater number of introductions have been tested under a wide variety of conditions. Reasonably good information is available on adaptation to climatic conditions. Some information has been obtained on adaptation to soils. Somewhat surprising has been the performance of native grasses, especially when several seasons of adverse climate were experienced. Information is badly needed on the response of many introductions and of planted native species to grazing under controlled management. This important field of research has hardly been touched.

Good stands of adapted perennials on reseeded range areas have increased production by either higher yields per acre or, as used by Miller et al. (45), have extended the grazing season, or both. There are as yet only a very few legumes for use in range reseeding, and much remains to be done in the selection or development of varieties and ecotypes of grasses. Improved varieties must have wide adaptation to the heterogeneous soil conditions and fluctuating climate that characterize the range area. Efforts to improve yield or some quality of range forage by breeding or selection must not narrow adaptation and should be directed toward the system of grazing management that will be used.

Very frankly, the user of the range areas in the West has paid primary attention to animal husbandry and has made notable progress in animal breeding and feeding. He is conscious of a decline in the ability of the range to provide adequate feed. There is recognition for eliminating the brushy and weedy invaders to the range and hope that new species of plants will somehow improve the amount of feed where they are seeded. Consequently, facilitating or third-order practices such as reseeding, brush eradication, and fertilizing have become popular and some are subsidized. Grass-management practices based on the physiology of species and the ecology of the community are not yet generally understood.

The few progressive operators who have been guided into an appreciation of range condition and have practiced grass management have been amply repaid, and, despite the vagaries of climate, they have developed management until it is an art as well as a science. Those who counsel with range users need understanding research to augment their experiences, but the investigator will do well to seek the advices and experiences of those who plan the ranches to guide their research efforts into even more productive channels.

SUMMARY

The forage resources of the 11 Western States are derived primarily from 10,009,000 acres of hay, 9,426,000 acres of pasture, and 542,425,000 acres of rangeland. Many of these kinds of forage (along with silage) are used in combination in the production of livestock products; hence, one often affects the others. Yields per acre within and among kinds of forage vary widely because great differences in soils, climate, and land-capability class characterize the West. Even so, field experience among farmers and ranchers and the results of research show that production can be materially increased by good grass-management practices.

Hay is the key to improved management of grazed forage crops on many farms and ranches in the West. Alfalfa provides 65 percent of the hay harvested. Studies show that at least 10 percent of the crop is lost by improper handling during curing, storing, and feeding and that much of this loss could be avoided. Research results show that material increases in yield per acre can be obtained by growing adapted varieties, applying P_2O_5, and using irrigation water correctly. Grass-alfalfa mixtures containing 30 to 35 percent of tame grass by weight have been shown to yield as much and have the same feeding value as alfalfa. In addition, mixtures prevent invasion of weeds and have a greater beneficial effect in soil and water conservation. The yield of hay from many of the 2,619,000 acres of native meadows can be increased by the use of N and P_2O_5 and, if irrigated, by applying water properly. The quality of this hay can be improved further by making an earlier first and then a second cutting.

A little more than 561 million acres of land are grazed by livestock. Yield of much of the 9,426,000 acres of tame pasture on cropland could be doubled, and the rangelands of the West have a forage potential that could provide for an estimated 5 million additional animal units. In both cases management is the key to greater per-acre production. Management of the grass crop by improved grazing methods, the use of fertilizers where applicable, and proper application of water on irrigated land are the principal means for increasing yield. Whether it be irrigated or dryland pasture or range, fundamental knowledge of the physiology of each species and of the ecology of the plant community is essential, both to the investigator and to the land operator.

Managing the grazing of forage crops to obtain sustained optimum production and stable plant associations is not simple. It requires a balance between plants, soils, and animals. Management becomes more complex when irrigation is used and on rangeland where wide fluctuations in climatic factors among years are common. Nevertheless there are now many instances where good management is being used with excellent results.

Research and experience have established several fundamental grass-management principles: Grass should not be grazed before readiness; repeated grazing during critical growth stages weakens many forage species; providing adequate regrowth periods between periods of grazing maintains stands and increases yield; grazing beyond an allowable percentage of utilization in dryland pastures or range or grazing late in the fall on irrigated land damages some or many species in the stand; using fertilizer in kind and amount where increments of production are known and sure to be profitable increases yield and net returns; and applying irrigation water in keeping with the seasonal and total needs of the plants in the pasture mixture can maintain desired composition, yield, and quality.

Research results and field experience, especially in the last 20 years, have shown what, when, and how to seed when establishing pastures on cultivated land and on abandoned farm or depleted rangelands. New varieties of several grass and legume species have been developed for the West. Several new varieties meet special needs such as are common to flooded areas or to saline and alkaline soils, others have particular seasons of use, a few have lower water requirement, still others are resistant to diseases or insects, and some have strong seedling vigor.

Much has been done in the West on methods for improving range condition and yield by removing undesirable invaders. By this means desirable forage species can develop, provided good grass management follows treatment.

Our knowledge of plants, their individual growth requirements, their response to good culture, and methods by which they can be improved has been greatly advanced in the past 20 years. Information is accumulating on the behavior of plant communities under different systems of management. Several improved management practices are in operation on planned farms and ranches. Even so, much remains to be known about many pasture and range species and their response to management and treatment. Much needs to be known about soil and water conservation to obtain optimum production and, in turn, maximum benefit from the grass crop growing on the land. More on-site fundamental research is needed, but much can be gained from combining research findings with results obtained on farms and ranches away from the experimental grounds.

The real job of increasing production through management is to expand planned application of known facts to the thousands of acres now providing forage crops but not managed to get optimum yields.

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