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ALFALFA PRODUCTION

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ALFALFA PRODUCTION

B. A. MADSON[1]

Alfalfa is the most important and most valuable field crop grown in California. It is exceeded in value by only one other crop, namely the orange, and practically equals the combined values of all our deciduous fruits, exclusive of grapes. In 1927, 1,001,000 acres were devoted to alfalfa, which produced an equivalent of 4,204,200 tons of hay valued at $52,552,500. It occupied slightly less than two-thirds of the total area devoted to hay production, and produced 81.4 per cent of the total hay crop. Only two other field crops, wheat and barley, approach alfalfa in total acreage, but they fall far below it in value.

Since 1909 the production of alfalfa has increased rapidly, as table 1 shows.

TABLE 1

ACREAGE AND PRODUCTION OF ALFALFA IN CALIFORNIA 1909–1927

Year	Acres	Acres, per cent increase	Tons	Production, per cent increase	Yield per acre
1909	484,134	.....	1,639,707	.....	3.6
1919	718,515	48.4	2,412,554	47.1	3.35
1927	1,001,000	39.3	4,204,200	74.2	4.2

In spite of the large increase in the production of alfalfa during the past score of years, prevailing prices fail to indicate any tendency toward overproduction. The reason for the continued high prices is not entirely clear. Alfalfa is fed to all classes of livestock, but the greater portion of it is fed to dairy animals. From 1909 to 1927, the production of alfalfa increased 156.4 per cent, while the number of dairy cows increased only 51.5 per cent.[2] True, during the same period the production of cereal hay decreased from 2,019,526 tons to 774,400 tons, but this decrease is largely offset by the decrease in the number of horses and mules. Cereal hay has, at any rate, never been used extensively as a dairy feed. The discrepancy must, therefore, be

[1] Associate Professor of Agronomy and Agronomist in the Experiment Station.

[2] Voorhies, E. C. Economic aspects of the dairy industry. California Agr. Exp. Sta. Bul. 437:20. 1927. (Out of print.)

accounted for in other ways. The general improvement of the dairy cows of the state, resulting in a larger consumption per animal, is doubtless a factor. Then, too, more alfalfa is being fed to other classes of livestock, particularly beef cattle and sheep. Limited quantities also are being shipped to eastern markets, while the importation from other states into California has shown a material decrease in recent years.

We are, however, still importing from other states considerable quantities of alfalfa hay to supply our dairy needs. As the acreage of new land suitable for alfalfa in California is rapidly diminishing, and as the number of dairy cattle must inevitably increase in order to supply the demands of an ever-growing population, we are probably in no danger of overproduction.

Alfalfa, unlike many of our other important crops, is not confined in production to a few localities, but plays an important part in the agriculture of all but a few counties of the state. Obviously, however, the greatest acreage and the greatest production are centered in those sections favored with an advantageous temperature, a long season, a good soil, and an adequate supply of water. According to the United States census of 1920, the eight counties of the San Joaquin Valley produced 54.8 per cent of the total crop of the state, while the counties below the Tehachapi produced 17.2 per cent and the Sacramento Valley 12 per cent. In addition, the mountain counties having considerable areas of suitable land, such as Lassen, Modoc, Shasta, and Siskiyou, also produced large quantities of alfalfa.

In 1927 the average yield of alfalfa in California was 4.2 tons per acre. As would naturally be expected, however, with a crop of such wide distribution, the yield in different localities varies greatly. Where the growing season is short or unfavorable, the soil poor, or the water supply inadequate, yields may be as low as 2.5 to 3 tons an acre; while in specially favored sections, 9 to 12 tons an acre are not uncommon. Under good average conditions, however, yields of 6 to 8 tons an acre may be considered very satisfactory.

It is interesting to note that in spite of the rapid increase in acreage, the average yield per acre has shown a substantial gain. Gratifying as this fact may be, there is every reason to believe that by a careful study of the problems involved in the growing of the crop, and by greater attention to details, the average yield per acre can be further materially increased—a result that would be of far greater benefit to the agriculture of the state than a corresponding increase in acreage.

VALUE OF ALFALFA LAND

Questions frequently asked, especially by prospective farmers contemplating the purchase of land for alfalfa production, are: What is good alfalfa land worth? What can I afford to pay for land for the production of alfalfa? It is impossible to answer these questions except in general terms, because the data available on the costs of production and on other economic aspects are wholly inadequate, and further because the returns vary so widely in different localities. All the writer can hope to do is to point out some of the more important factors which must be considered as having a bearing on land values, or to give what are now regarded as proper values in some of the older alfalfa-growing sections.

According to the 1927 figures, the average yield of alfalfa in California was 4.2 tons per acre and the farm value $12.50 per ton. If we assume that it cost $8.50 a ton to produce the crop, including labor, water and taxes (this figure is probably not far wrong) the average net return would be $16.80 an acre or 6 per cent on a $280.00 valuation. Whether a farm value of $12.50 a ton is a safe figure may be questioned; for although everything indicates that the value of alfalfa will remain high in the future, it will doubtless, in many seasons, fall below this figure.

In any consideration of returns and land values, the yield which may be expected is always important; a high yield usually means a low per-ton cost of production, for many of the items of cost are fixed. Other factors to be taken into account are cost of labor, water, and the like. Water costs vary greatly, ranging from less than $5.00 to more than $25.00 an acre per season. Aside from the cost, the adequacy of the water supply itself, and the possibility of obtaining it throughout the season, will materially influence land values.

Is the hay to be fed on the farm and marketed as dairy or other animal products, or is it to be marketed direct? Usually the greatest returns are obtained from the crop if it is fed on the place, especially in localities at some distance from the market. If the hay is to be marketed direct, the quality of the hay and the proximity to market are important considerations. Alfalfa hay is a bulky product; its cost of transportation is relatively high, as table 2 will show:

It will be noted, for example, that the cost of shipping alfalfa hay from Bakersfield to Los Angeles is $1.50 more than from San Bernardino. On the basis of a six-ton crop, this would amount to

$9.00 an acre per year, or 6 per cent on $150.00. Other things being equal, land near the latter point should, therefore, be worth $150.00 more than at the former. As a matter of fact, however, other factors may offset this difference.

TABLE 2

FREIGHT RATES ON ALFALFA HAY FROM LOCAL POINTS IN CALIFORNIA TO CENTRAL MARKETS

(Per ton in an 18,000-pound car)

	To Los Angeles	To San Francisco
El Centro	$5.00	
San Bernardino	2.80	
Bakersfield	4.30	
Lancaster	3.00	
Fresno	5.00	$3.50
Patterson		2.80
Woodland		2.10
Gerber		3.50

In case the hay is grown for market, the quality of the product has a very marked influence upon its value and the returns obtained. At the central markets, differences of $4.00 to $6.00 a ton between high-grade and low-grade hay often exist, so that the man who is producing a low-grade product may be doing so at a loss, while another man producing a high-grade product under similar conditions, may be making a handsome profit. The production of high-grade hay is largely an individual matter, depending upon the way in which the crop is handled, but climatic differences make it easier to produce a good grade of hay in some sections than in others.

The value of improved alfalfa land in California varies from less than $200 an acre in some of the more isolated districts, to more than $500.00 an acre in sections favorably located with regard to both production and market. At the present time, however, there are very few sections where alfalfa will consistently produce returns at the latter valuation. Taking, as a whole, the larger alfalfa-producing districts, such as the San Joaquin, the Sacramento, and the Imperial valleys, the average maximum valuation on which profitable returns may be obtained will probably be in the neighborhood of $350.00 an acre, varying from less that $300.00 an acre to about $400.00. Unimproved land will usually be worth $100 to $150 an acre less, because it costs about this amount to develop the land and get it into good productive condition.

FACTORS AFFECTING YIELD

The factors of greatest importance in influencing the yield are climate, the character and fertility of the soil, and the water supply. In most sections of California, the soil and the water supply are probably more often limiting factors than the climate, although the effect of the latter is undoubtedly very marked in many cases. High or low yields, however, are often due to a favorable or unfavorable combination of all three rather than to a single factor.

Climate.—As far as climate is concerned, alfalfa can be grown satisfactorily in all the important agricultural sections in the state. Winter temperatures low enough to cause winter killing of even our common alfalfa occur in only a few minor sections and need no consideration. The climatic factors which have the greatest effect on yield are the length of growing season and the temperature during the growing season.

Alfalfa, unlike many other perennial plants, does not appear to have a definite period of dormancy. Growth takes place whenever the temperature goes above a certain minimum, and ceases when it again drops below this minimum, which is about 50° F. In sections, therefore, with a considerable proportion of warm days during the winter months, growth, though slow, may be practically continuous. Obviously, then, in sections such as the southern part of the state, where warm weather comes on earlier in the spring and continues late in the fall, the length of the growing season, and hence the number of cuttings obtained per season, will be greater than in sections where the winters are longer and colder.

The temperature for the optimum growth of alfalfa has not been definitely determined, but we do know that in some sections the optimum is exceeded during a part of the growing season to such an extent that growth is definitely checked. In the Imperial Valley, for example, the most luxuriant growth is obtained in the spring and fall. During the heat of the summer, on the other hand, growth is very much depressed even on good soil well supplied with water. High temperatures during the summer may also check growth to some extent in the large interior valleys, but the effect is much less pronounced.

Soil.—In California, alfalfa is grown successfully on many soil types. The type of soil is of little importance provided it is deep and friable enough to permit the ready penetration of the water and the plant roots, and is well supplied with the mineral elements neces-

sary for plant growth, especially lime, phosphorus, and sulfur. Good drainage is also necessary, and the soil must not contain excessive amounts of alkali salts. The soil should, in addition, be well supplied with organic matter, or humus, although some excellent yields of alfalfa have been obtained on soil deficient in this constituent. Generally, however, addition of organic matter on such soil will increase the yields materially.

The requirements, as given above, are most often found in the deep, sandy loam, silt loam, or clay loam soils, which in consequence, are regarded as the most favorable for alfalfa. Good stands and good crops are, however, often obtained on other soils as well. Some of the very sandy soils produce remarkably good crops in spite of the fact that they are deficient in organic matter and low in available mineral nutrients. Their lack in fertility is offset by the ease with which the plant roots can penetrate to great depths and so give the plant a very large volume of soil in which to forage. Such soils require fertilization sooner than the heavier type if good yields are to be maintained. When the farmer has once determined the fertilization necessary to maintain production on these soils, the advantage of good drainage and permeability will perhaps more than offset the lack of fertility.

The heavy soils, especially those containing a large amount of clay, are as a whole probably the least desirable for alfalfa. Their compact structure and their tendency to swell when wet render them almost impervious to water. On most soils of this type, irrigation water rarely penetrates to a depth of more than 18 inches or two feet. The plants are, in consequence, shallow rooted; their feeding area is limited, and the growth is usually short. The first cutting or two in the spring may be very good, the light crop occurring during the summer and fall. Subsoiling has been widely advocated as a means of correcting this condition, but its value is usually reduced by the fact that most of the heavy soils are very colloidal and run together easily. More frequent irrigation may, in certain cases, effect some improvement in the crop, but this increases the cost of production and frequently also aggravates the weed problem. The liberal application of barnyard manure has as a rule brought about the greatest improvement in the crop on heavy soils. In numerous recorded instances the use of manure has transformed very poor fields into fields whose crops compare favorably with the production of the best soils in the locality. The manure not only makes the surface soil more friable, but greatly promotes the absorption and penetration of

the irrigation water, as well as the penetration of the plant roots. The point to be emphasized, however, is that heavy applications of manure are necessary to get results.

Water Supply.—Alfalfa, as grown in California, is essentially an irrigated crop. About 80 per cent of the acreage is irrigated, and a considerable part of the remaining 20 per cent is grown on land with a water table close enough to the surface to supply the needs of the crop. As the alfalfa plant uses a large amount of water and grows for eight to ten months of the year, an adequate supply of good water free from alkali or other injurious ingredients must necessarily be available throughout the growing season. Production, in many districts, has been seriously handicapped by the exhaustion of the water supply in the late summer or early fall and the consequent elimination or reduction of the fall cutting.

The amount of water required for alfalfa varies somewhat with local conditions, but experience has shown that as a rule 2½ to 3 acre-feet properly applied is sufficient for the production of maximum yields.[3]

Although, as already stated, certain districts suffer from a shortage of water, a much larger acreage of alfalfa unquestionably suffers from too much water rather than too little. Over-irrigation is in fact the direct cause of many of our alfalfa troubles. It not only leaches the soil and reduces the yields, but is also responsible for a large proportion of our drainage and alkali troubles. Untold benefit would accrue to the alfalfa industry if more attention were given to the efficient use of water, which would include more careful leveling and a proper coordination between the flow or head of water used and the size of the checks. The excessive use of water increases the expense of production needlessly, reduces the yield, and often ruins the land. The cost of water varies greatly. It is usually cheapest when obtained from impounded sources through properly organized and conducted irrigation districts, and most expensive when pumped from deep wells. The actual cost per acre-foot ranges from about $1.50 to as high as $7.50, so that these factors alone may contribute materially to the expense of producing the crop.

Unfavorable Soil Conditions and Their Correction.—In addition to the problems arising from soil type, a number of other conditions may militate against a good crop. The most important of these are

[3] Beckett, S. H., and M. R. Huberty. Irrigation investigations with field crops at Davis, and at Delhi, California, 1909–1925. California Agr. Exp. Sta. Bul. 450:1–24. 1928.

poor drainage, hardpan, or other impervious substrata, and alkali, all of which may be interrelated.

Drainage.—Good drainage is essential to a good vigorous growth of alfalfa, particularly if the field is to remain productive for a reasonable period of time. Poor drainage, however, is of common occurrence, and is often the result of overirrigation. It is usually manifested by a high or rising water table. The evidence as to the effect of a high water table on alfalfa is conflicting, for in some localities good stands and good crops are obtained with the water table rather close to the surface. This, however, is usually in soil where the water table is naturally close to the surface, with but little seasonal fluctuation, so that the soil and the plant have adjusted themselves to that condition. Where the high water table has been brought about by overirrigation or some other artificial means, or where it fluctuates greatly from season to season, the crop will usually be poor and the stand short-lived.

Ordinarily alfalfa roots will grow downward until they strike saturated soil or some obstructing layer. Then, if the water table rises, the submerged portion of the roots will rot off, greatly weakening the plants. This is especially apt to occur if the rise takes place during the growing season when the roots are active; at this stage the complete exclusion of the air for even a few days may be very injurious. During the winter months, when the plants are more or less dormant, the roots will tolerate submergence for longer periods without injury.

A high water table is, furthermore, undesirable because it limits the feeding area of the plants and results more quickly in poor growth owing to soil exhaustion. In addition, it frequently causes alkali to accumulate at the surface to such an extent that the land is rendered unfit for alfalfa or any other crop. Large areas of alkali wastes have, in fact, been created in this way.

How close the water table may be allowed to come to the surface without injury to the crop or the land will obviously vary with the type and nature of the soil. On good soil, as a rule, alfalfa can be grown with success if the water table is three feet or more below the surface and stationary; but if it is closer than this or if it has considerable seasonal variation, troubles may be anticipated.

The solution, of course, is proper drainage which will hold the water table as far below the surface as possible. In most cases, the individual farmer is practically helpless, the problem being one which requires community action. Many irrigation districts are suffering

from high water, and sooner or later unless proper drainage is instituted, much of the land will be ruined. More careful irrigation would also, to a large extent, prevent the trouble. Too many farmers, especially alfalfa growers, apply water in much larger amounts than is required by the crop; the excess accumulates in the soil and causes the water table to rise. In many districts, if the land were properly prepared, and only enough water applied for the needs of the crop, there would be no drainage problem.

Hardpan.—Many California soils contain hardpans. Their composition and their depth below the surface vary with the character of the soil and the conditions under which they have been formed. They are objectionable mainly because they prevent alike the penetration of water and of plant roots, and, if close to the surface, limit the feeding area of the latter. Some hardpans also contain soluble salts which, upon the application of water, go into solution and may be drawn to the surface where they form an alkali condition. Such impervious layers should, whenever possible, be broken up. If they are within two feet of the surface and not very thick, this breaking can often be done with a subsoiler. When they are more than two feet below the surface or of considerable thickness, blasting is the only effective means, and this at best is expensive. If the hardpan layer is three or four feet or more below the surface and overlaid with good soil, excellent crops may be grown in spite of its presence, provided care is exercised in the use of the irrigation water.

Alkali.—Excessive amounts of alkali or salts in the soil is a condition which prevails in many sections of California; and the removal of such salts and the reclamation of the land for crop products are among the most difficult problems confronting agriculturists today. Alkali consists mainly of the sodium salts of carbonate, bicarbonate, chloride and sulfates. The carbonate and bicarbonate constitute the so-called 'black alkali,' which is far more toxic to plant life than the chlorids and sulfates or 'white alkali.' Alkali occurs chiefly on poorly drained land and is frequently accompanied by hardpan. Large areas of once excellent land have become alkali wastes as the result of over-irrigation, the rising water carrying the salts to the surface, where they have accumulated in such quantities as to render the soil unfit for plant growth. As already indicated, the reclamation of alkali land is difficult, especially if the soil is heavily charged with black alkali. The providing of good drainage and a heavy leaching of the soil to remove the salts have been recommended, but in many cases this method has failed to produce satisfactory results. Usually the soil

becomes tight and sticky, the water penetrating so slowly that leaching becomes impossible. Only recently have investigations shown the cause of this condition. When large quantities of salt are present, the sodium reacts with certain clay constituents, replacing the calcium and greatly altering both the chemical and physical condition of the soil. This sodium clay complex is apparently the cause of the colloidal conditions of alkali soils, and the reason why they bake upon drying and, in general, are difficult to handle.

To reclaim such soil, it is necessary first to replace the sodium with calcium in order to improve the physical condition so that leaching is made possible. One of the best materials to bring about this condition is sulfur, provided calcium is already present in the soil in the form of lime. The sulfur helps to bring the calcium into solution in sufficient quantities for the desired reaction to take place. The beneficial effect of gypsum on black alkali soil has long been recognized; the reason is that gypsum (calcium sulfate) is partially soluble and thus provides considerable soluble calcium, which will react to replace the sodium in the clay compound. On bad alkali soils, however, the amount of gypsum required to bring about complete removal of the alkali will often be so large as to be prohibitive. Data are yet too meager to permit a definite statement as to the amount of sulfur which must be applied, but 1,000 pounds or more per acre will probably be required, depending upon the amount of alkali present.[4]

The procedure in this process is to apply the sulfur to the soil and work it in. The land is then kept moist and in as good tilth as possible for a few weeks or months, in order that oxidation may take place, and then leached heavily to remove the salts. Although complete removal of the alkali may not be possible with a single treatment, bad alkali land has been so far reclaimed that excellent stands and crops of alfalfa have been obtained the following season.

Old alfalfa plants, as has frequently been observed, will tolerate as strong alkali as any crop that we have, but the young plants are very susceptible and easily destroyed. On land that is badly impregnated with alkali, stands have sometimes been obtained by washing the salts from the surface soil and keeping them down by frequent irrigation until the plants are well started. When such a procedure is necessary, however, the crops will seldom be as heavy, nor will the

[4] For further details see Kelley, W. P., and E. E. Thomas. Reclamation of the Fresno type of black-alkali soil. California Agr. Exp. Sta. Bul. 455:1–37. 1928.

stand last as long as on soil free from alkali. In the long run, the removal of the alkali by soil treatment, leaching, and draining will be far more satisfactory.

FERTILIZATION OF ALFALFA

Although alfalfa makes a heavy draft upon the mineral elements of plant food, there is no indication as yet that fertilization is necessary on most of our soils, nor any likelihood that a general program of fertilization will be necessary for some time. Our best alfalfa land will, if kept in proper physical condition, probably continue to produce satisfactory crops for an indefinite period.

On the other hand, the evidence accumulating shows that on many soils the use of fertilizer in the proper form will produce marked increase in the yields of alfalfa. Apparently the elements most likely to be deficient are sulfur, phosphorus, and (in rare cases) potassium. Farmers in some sections have long made use of gypsum as an alfalfa stimulant, although that substance has but recently been shown to possess a definite fertilizing value. In recent years, numerous tests conducted under the direction of county agents have shown that on many soils applications of sulfur produce marked increase in yields. In most cases at least, the beneficial effect of gypsum is clearly due to the sulfur which it contains, and soil that responds to gypsum will also respond to sulfur, the response varying only in degree. In some cases, also, increased yields have followed the application of phosphorus, but apparently soils deficient in phosphorus are far less numerous than those deficient in sulfur. Unfortunately no chemical or physical tests now available can determine with any degree of accuracy the fertilizer needs of the soil. The only way to ascertain whether fertilizers are required is to try them out under field conditions. The results of such tests are, furthermore, very limited in their application, being confined, in fact, to the particular body of soil on which the tests are conducted. The same soil in a different locality may and often does give an entirely different response. If in doubt, therefore, as to the fertilizer needs of your alfalfa, try out the various forms on a small scale first before attempting to treat the whole field.

Where sulfur is required, applications of 150 to 200 pounds per acre, worked in during the fall or winter, have ordinarily proved sufficient. Since sulfur must undergo oxidation before it becomes available, winter applications often show little or no effect until summer or early fall. To overcome this delay, some farmers apply 300 to 500 pounds of gypsum with the sulfur; the gypsum, being imme-

diately available, stimulates the spring growth up to the time when the sulfur becomes available. The effect of gypsum, however, never lasts so long as the effect of sulfur. One application of sulfur will ordinarily suffice for two years, when the treatment must be repeated. Any form of finely ground agricultural sulfur will serve the purpose. Under California conditions, there seems to be little virtue in the specially prepared or so-called inoculated sulfur. Apparently our soils contain sufficient sulfofying bacteria to bring about the necessary oxidation.

When phosphorus is needed, the best form to use is superphosphate, and the optimum application is about 200 pounds per acre, applied in the winter or early spring when growth is starting. Such an application will ordinarily show immediate results, and will be effective for not more than two seasons. Frequently a lighter application each season will be found more economical.

Lime, though employed extensively in the eastern states on alfalfa and clover, has found but little use in California. In the humid regions, the main reason for its use is to correct soil acidity, a condition extremely rare in alfalfa soils of this state. Applications of lime also tend to improve the physical condition of heavy soil, but to secure any appreciable results such large quantities must be used that the cost is, as a rule, prohibitive.

Barnyard manure is nearly always good for alfalfa, especially on very light or very heavy soils. Failure to secure appreciable results with manure can usually be traced to the use of too light an application. Occasionally light applications will prove beneficial, but as a rule, heavy treatments are necessary for satisfactory results. The best time to apply manure is when the land is being prepared for the crop. Eight to ten loads or more per acre, thoroughly incorporated with the soil, will usually greatly increase growth. Liberal surface applications of well-rotted manure on an old stand will also, as a rule, materially stimulate and increase growth. Coarse, strawy manure should not be used for surface dressing because much of the undecayed litter will be raked up in the hay. Some farmers, especially on sandy land, have secured very striking results by applying a heavy surface dressing of well-rotted manure immediately after seeding. The manure, acting as a powerful stimulant to the early growth, greatly increases the first season's crop. It tends, in addition, to check the blowing of the soil. This practice can be increased to advantage, especially where the crop is short-lived, in order to secure maximum yield during the short period in which it occupies the land.

Alfalfa in the Rotation.—Much has been observed and written regarding the effect of alfalfa on other crops in rotation, but no studies and but few observations have been made with regard to the effect of the rotation on the alfalfa itself. The importance of the crop to the agriculture of the state, and the difficulties which growers in the older sections are experiencing in securing and maintaining stands render this phase of the problem worthy of some attention.

It has long been recognized that it is difficult to secure a satisfactory stand or growth of alfalfa if seeding is done immediately on alfalfa sod, or soon after an old stand has been plowed under. For this reason, most growers, after plowing up an old stand, farm the land to annual crops for a year or two before again seeding to alfalfa. In most cases, however, no thought has been devoted to the type of crop used, except that the crop preceding the alfalfa should not seriously interfere with the preparation of the land. In the older sections, where several plantings of alfalfa have occupied the land, one or two years of annual crops are now known to be insufficient; three or four years are necessary if the grower is to be sure of getting a good stand and growth. The reasons for this situation are still obscure. A number of theories can be advanced to explain the difficulty, but none of them are as yet supported by facts. The following observations, however, aid us in adapting our practices to meet the situation until more definite information is available.

It has been observed that when leguminous crops such as beans or cowpeas are grown for two or more years, almost as much difficulty may be experienced in getting a good stand or growth of alfalfa as if it had been seeded on old alfalfa sod. Apparently part of the difficulty is associated with the legume itself, indicating that such crops should be used sparingly in the rotation. It has further been observed that if the intervening crops were irrigated heavily, more time must elapse before reseeding to alfalfa than if they received little or no irrigation. When corn, sorghum, sudan grass, or small grains are grown without irrigation, the land will usually be ready to go back to alfalfa within two or three years.

Special treatments have, in some cases, been employed to overcome the difficulty. Surface dressing the field with well-rotted manure just after seeding will often stimulate the growth of the young alfalfa so that no injurious effect of the previous cropping treatment will be noted, even when the new seeding is made within a year after the old stand has been plowed under.

Numerous exceptions to these observations in no way lessen their value. Fortunately the problem has become acute in only a few localities, and the above observations are included mainly to call attention to a phase of the alfalfa problem little understood, but likely to demand more attention as time goes on.

VARIETIES OF ALFALFA

Only two varieties of alfalfa are of economic importance in California at present: the common or Chilean, and the Hairy Peruvian. Both are of the blue-flowered type, the latter being larger, coarser, and hairier of leaf and stem than the former. The Hairy Peruvian also possesses the ability to grow at lower temperatures than the common; it starts growth earlier in the spring and continues later in the fall. In the Imperial Valley and a few other sections, it will make considerable growth throughout the winter, and will provide an appreciable quantity of green feed or pasture.

Some years ago, the Hairy Peruvian bid fair to replace the common in portions of the San Joaquin Valley and southward, but in recent years its popularity has so waned that it is now of importance only in the southern end of the state, where it consistently outyields the common.

The reason for its decline in popularity is that, being coarse stemmed, it produces a poor quality of hay unless cut young. When continually cut before blooming, the plants are weakened and the stand thins rapidly, which has given the Hairy Peruvian the reputation of being short-lived. In general, therefore, it may be said that from the Tehachapi northward, the common alfalfa is the best variety for most conditions, while in the southern end of the state, and especially when winter feed is desired, the Hairy Peruvian has advantages. Even in this section, however, the grower of market hay still prefers the common.

Some interest has been expressed in the possibilities of Grimm alfalfa, especially for shallow soils or on land with a high water table. Unfortunately almost nothing is known as to its behavior under such conditions in California, but the experience of other states indicates that it is just as susceptible to injury from adverse soil conditions or high water table as our common alfalfa. Trials in Mendicino County indicate, however, that it is superior to other varieties for that section, and it may be equally good for other sections, especially in the north coast districts. One should bear in mind, however, that the

chief value of the Grimm alfalfa is its resistance to winter killing, which is not a factor in most of the alfalfa-growing sections of California. At any rate, it should be used sparingly until more definite information as to its value is available.

PREPARATION OF THE LAND

Since alfalfa is a perennial crop, normally expected to occupy the land for several years, special attention should be given to putting the land in proper condition for irrigation, to the preparation of the seedbed, and to getting the crop started. This is important to insure not only good yields but also as efficient and economical handling of the crop as possible.

Leveling and Checking for Irrigation.—Nearly all land that is to be irrigated requires some leveling and checking in order that the water may be distributed evenly and properly controlled. The only exception to this rule is on very sandy porous soils for which only a small head of water is available. Here the water is sometimes distributed through slip-joint pipes, laid out across the field and then gradually disjointed as each limited area around the discharge of the pipe becomes supplied with water. This method leaves the field free from levees, but it entails a large amount of labor in applying the water, results in non-uniform distribution and is not to be recommended where other methods can be used.

Of the various methods of checking, the basin and contour check are still used to some extent, but the border or strip method, more popular in California, has many advantages. By the use of borders, the number of field ditches or laterals is reduced to a minimum, and the water can be applied uniformly without a great expenditure of labor. The fields are, furthermore, in regular lands which do not greatly inconvenience the use of the harvesting equipment. The method is applicable to any land which has a uniform but gentle slope.

Border checks, when properly made, are level cross-wise between the levees, with a gradual slope from the head ditch to the lower end. The size of the check and the grade allowed depend mainly on the head of water obtainable and on the soil type. The common tendency is to make the checks too large and especially too long, the object being to reduce the number of field ditches. Very long checks or runs invariably result in unequal distribution of the water. The upper end of the check gets too much water before the lower end is supplied.

Before the checks are laid out, therefore, all factors should be considered, and the size and length determined accordingly. Short, narrow checks should be used if the head of water is small and the soil light or sandy. With large heads of water or on heavy soil, larger and longer checks may be employed. Table 3, prepared by J. B. Brown[5] is an excellent guide to follow.

TABLE 3

SIZE OF BORDER CHECKS

Head of water delivered to each check	Sands		Loams		Clay	
	Breadth	Length	Breadth	Length	Breadth	Length
*Cu. ft. per sec.**	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*	*ft.*
1	20–30	200–300	30	300–400	30	440– 660
1–2	30–40	300–400	30–40	440–660	30–40	660
2–4	30–40	440	40	440–660	50	660– 800
4–8	40	440–600	50	660–880	50	880–1320

* One cubic foot per second=450 gallons per minute=40 miner's inches (statutory standard) or 50 miner's inches (southern California standard).

For basin or contour checks, the same factors as those given for borders are used in determining sizes. The contour checks particularly are often used on land which does not lend itself readily to the border system.

Contour checks may be and usually are irregular in size, but large checks should be avoided except in heavy soil or where a large head of water is available. With either of these methods, the aim should be to have the area within each check nearly level or with only a slight slope away from the inlet ditch. The water should be supplied to each check directly from a field ditch or lateral. The practice of arranging for the water to flow from one check into the next lower, as in irrigating rice, never gives the best results. The large amount of water necessarily applied to the first checks will drown or scald the alfalfa plants, destroy the stand, and reduce the yield prematurely. The method is, in addition, wasteful of water.

The furrow or corrugation method so popular in Utah and Idaho has not been used to any extent in California, although under certain conditions it might be used to advantage. By this method the land is usually leveled sufficiently to remove rises or depressions, and to provide a gentle slope in one direction. Furrows or corrugations 16 to

[5] Brown, J. B. Irrigation of alfalfa by border or strip check method. California Agricultural Extension Service Leaflet. 7*p*. 1929.

24 inches apart are then run down the slope. Irrigating water, in a small stream, is then run down the furrows until the soil is moistened sufficiently. The method is said to be particularly advantageous on land that is inclined to bake or which takes water slowly.

Leveling should be done in the late summer or fall when the soil is dry. There is then no danger of puddling or of injuring the physical condition of the soil as is the case when it is wet. If the land has been in annual crops for some time, the best procedure is first to plow deep enough to break up any plow pan which may be formed. The field is then rough-leveled with a Fresno, the high spots being removed and the depressions filled until a uniform slope is obtained. The levees are then marked out with a plow by throwing together a back furrow where the levees are to be located. Next the levees are built by going across the field with a Fresno, removing a uniform layer from the surface of each check and dropping at the levee. Two or three Fresno loads are usually sufficient for each levee, depending upon the size of the check and the head of water to be used. After the rough work is done, the levees are shaped up with a crowder. When completed, they should be firm enough to hold the water within bounds, but broad and rounded so as not to interfere unduly with the operation of the implement and the handling of the crop. After the levees have been built, the leveling of each individual check is completed, first with a Fresno and finally with a rectangular leveler or other suitable implement. Where heavy fills have been made, it is a common practice to settle the soil by irrigating as soon as leveling is completed, and if depressions appear, to relevel as soon as the surface is dry enough to work.

Preparation of the Seedbed.—Alfalfa, in common with most small-seeded crops, cannot be planted very deep, and hence needs a well-prepared seedbed for a good stand. Almost any effort to attain this end will be justified, but if the work is done at the proper time and in the proper manner, the cost need only be nominal.

After the land has been leveled, the soil will usually be hard and packed, and should be loosened while still dry. A good implement for this purpose is the chisel cultivator (fig. 1), which will loosen the soil to a depth of several inches without seriously disturbing the level of the check. The spring-tooth harrow will serve the purpose on light soils but is not heavy enough for the heavier soils. Some farmers plow the check to loosen the soil after leveling, plowing in lands of two borders each, and using the levee between as the back furrow. The objection to plowing, however, is that the furrow left at the base

of the alternate levees must be filled in by repeated cross working before the land can be seeded.

If the alfalfa is to be seeded in the spring, the land should not be worked down after chiseling or plowing in the fall, but should be left rough until seeding time next spring. In the rough condition it becomes better aerated, absorbs the winter rainfall more readily, and does not puddle or become so hard and compact as when worked down to a smooth condition. The seedbed proper should be prepared just before seeding time in the spring.

A good seedbed for alfalfa is firm and moist, with an even, fairly fine mulch not more than 1½ inches deep. Unless the weed growth has been heavy, one or two workings with a spring-tooth harrow followed by a smoothing harrow will usually do the job. Many farmers use the disk in place of the spring-tooth, but the land must subsequently be gone over with a smoothing harrow to remove any ridges which may have been formed. During the preparation of the seedbed, the levees should be cultivated until they are smooth, well rounded, and in seedbed condition.

The preparation for fall seeding is essentially the same as for spring seeding, except that after the deep cultivation the land is first irrigated to settle the soil and to provide the moisture necessary for growth. Then, as soon as the surface is dry enough to work, the seedbed is prepared and the crop planted.

SEED AND SEEDING

Choice of Seed.—Only the best seed available should be used. It should be plump, clean, and of high germination. Good seed should germinate at least 85 per cent, and should be free from noxious weeds such as dodder, Johnson grass, and Bermuda grass. If there is any doubt as to the quality of the seed available, a sample of ½ pound should be sent to the Seed Laboratory of the State Department of Agriculture, Sacramento, California, for a test.

The source of the seed does not appear to be important, provided it has not been grown in regions with climatic conditions radically different from those in which it is to be planted. Seed grown in northern California and that grown in southern California will apparently do well in most sections of the state. It is not advisable, however, to secure seed from other states, especially from those with rigorous climatic conditions; such strains have ordinarily been developed for cold resistance and hence have a slow rate of growth.

Time of Seeding.—Alfalfa may be seeded in some portions of the state at almost any season of the year, but in the major alfalfa-growing sections the most favorable time for seeding is either early in the spring (from the middle of February to the first of May) or in the fall (during September or early October).

In the extreme south, later fall seeding or even winter seeding is often practiced. The most unfavorable time in any section is during the summer when the weather is hot and dry. The common practice in most parts of the state is to seed early in the spring, the most favorable period being from the middle of February to the first of

Fig. 1.—The chisel cultivator is an excellent implement for working up the soil in preparation of the seedbed.

April. At this time of the year, the weed growth which has come on during the winter is readily destroyed, and the seedbed can be prepared with a minimum of effort. The soil is usually moist, and the temperature is high enough for rapid germination of the alfalfa seed and rapid growth of the plants, but not so high as to cause the seedbed to dry out rapidly, as will be the case later in the season.

Fall seeding can be practiced only where a supply of irrigation water is available throughout the season. The land must be irrigated to fill the soil with moisture. As soon as the surface is dry, the seedbed is prepared and the crop sown. Later irrigation may be necessary to keep the crop going, especially if the land dries out rapidly or if the first rains do not arrive until late. As a rule, fall-sown

alfalfa should be seeded in September or early October, so that the plants will become well established before cold weather slows up their growth. In the Imperial Valley and a few other favored localities, even December seeding gives good results, but this does not hold true throughout the state as a whole.

Both spring and fall seeding have their advocates, and each is attended with certain advantages and disadvantages. As already indicated, a good stand can usually be secured with considerable ease in the spring, and without undue interference from weeds. On heavy soils, however, beating rain after seeding sometimes packs the soil so that poor germination results, often necessitating reworking the land and resowing. The chief objection to spring seeding is that inasmuch as two or three months must pass before the plant can become established, only a few light cuttings, and usually less than half of a full crop, can normally be expected the first season.

In the fall, on the other hand, it is usually more difficult to secure a good stand, for although a good seedbed may be prepared, the warm, dry weather, causing the soil to dry out rapidly, will result in a poor germination and a destruction of many of the young plants. Furthermore, unless the crop is put in early enough so that the plants become well established, the heavy weed growth which inevitably occurs during the winter will crowd out many of the weaker seedlings so that by spring the stand will be seriously depleted. The chief advantage of fall seeding is that the plants, having secured a good start, will be ready to renew rapid growth as soon as the weather warms up in the spring; a very good crop can, therefore, be secured the first season. This advantage, in many cases, more than counterbalances all the other difficulties, especially where the productive life of the field is limited to three or four years.

Method of Seeding.—The drill is now almost universally used in California for seeding the crop, and this method has so many advantages over broadcasting that the latter should be abandoned as rapidly as possible. With the drill the seed can be distributed more uniformly, and, more important still, it can be placed below the surface of the soil at any uniform depth desired. The special alfalfa drill which spaces the rows four inches apart is doubtless the best implement to use, but the regular grain drill with rows six inches apart will, if it can be adjusted to seed at the proper rate, serve very well. Theoretically, the four-inch drill will give a better distribution of the seed and a larger percentage of survival of the young seedlings, during the early stages of growth, but at best only a small percentage

survive as the plants develop, and these spread out and completely occupy the intervening spaces even with 6-inch drill rows. As far as the writer is aware, there is no evidence that the results will be appreciably better with one type of drill than with another. The important point is that a uniform depth of planting is obtained, and this gives all the seedlings a rapid, uniform, and equal start.

Drilling should be done across the check so that the levees as well as the checks will be seeded. Although this is rather inconvenient, the levees do not offer a serious obstacle unless they have been made too narrow and steep, and in no other way can the levees themselves be properly seeded. The inexperienced grower sometimes still follows the line of least resistance, and drills lengthwise of the checks, leaving the levees bare to produce weeds. It should be remembered that the levees often constitute from one-tenth to one-fifth of the total area of the field, too large a proportion to be left without producing any direct return.

The depth of seeding should ordinarily not exceed one to one and one-half inches. While the seed must be planted deep enough to come in contact with moisture, if the seedbed has been properly prepared this can be done without exceeding the depth given. If the seed is planted too deep, the small amount of reserve material stored in it will be exhausted before the seedling reaches the surface, and the result, obviously, will be a poor stand. The optimum depth of planting varies also with the soil type. On sandy soils the seed can and usually must be planted deeper than in the heavy soil.

Rate of Seeding.—In practice the rate of seeding alfalfa in California varies from less than 10 pounds to as high as 30 pounds per acre. If all the seed germinated and produced healthy, vigorous plants, even a few pounds of seed per acre would provide an excellent stand. Under ordinary conditions, however, many of the seeds fail to germinate, and many of the young seedlings perish for one cause or another soon after reaching the surface; experience has shown that a heavier rate of seeding is generally necessary for a satisfactory stand. The average rate of seeding is between 15 and 20 pounds per acre. If the seedbed is in poor condition, or if the crop is being put in at a time when the weather conditions are not so favorable for the young plants, even a heavier rate must be used. Because of the difficulty of preparing a good seedbed in the fall, and because of the warm, dry weather that prevails at that season, fall seeding must, as a rule, be 20 to 25 per cent heavier than spring seeding under the same conditions if a satisfactory stand is to be secured.

Use of a Nurse Crop.—A question still frequently asked is whether it is advisable to seed a nurse crop with the alfalfa. A nurse crop is rarely necessary or advisable. About the only conditions under which there is any justification for using one is in the windy sections where the shifting soil may destroy the young seedlings before they become well established. Here a light seeding of rye, barley, or some other cereal will help hold the soil and thus protect the alfalfa plants. The seeding should, however, be light, for the vigorous growth of the cereal will compete with the alfalfa for moisture, and will eventually crowd and shade out many of the seedlings and thereby reduce the stand. Twenty-five to 30 pounds of rye or wheat, and 20 pounds of oats or barley, is all that should be used in any case. The same results can often be obtained by applying a light surface dressing of manure immediately after seeding. The manure will reduce the soil movement and will stimulate rather than compete with the young alfalfa plants.

Reseeding Old Stands.—When the stand begins to thin out and the yield goes down, the first question is, naturally, whether or not we can thicken the stand by reseeding in the old growth. This has been done, but it is difficult to get new plants to take. It is difficult because, as already stated, young alfalfa is strangely averse to growing in the presence of old alfalfa plants or on land that has recently grown alfalfa. Only a few of the seedlings which do appear will, furthermore, withstand the competition and the shading effect of the older plants. Most of the attempts to maintain fields by reseeding in old stands have been failures. On the other hand, a few market-hay growers are reported to have maintained satisfactory stands for a number of years by cultivating the fields, broadcasting 12 to 15 pounds of seed each spring, and keeping the old growth cut back until the new plants were established. The spring clipping must result in considerable loss in the spring crop; whether this loss will be offset by the thicker stand can be determined only by carefully conducted trials. In the light of our present knowledge, the practice cannot be recommended. When the stand has thinned to a point where the yield and quality of the hay is affected, it is safer to plow the field, rotate for a couple of years, and then reseed.

INOCULATION

Alfalfa, in common with other legumes, requires for its best development the presence of the symbiotic bacteria which live upon its roots and gather nitrogen from the atmosphere. These organisms cause the nodules on alfalfa roots, supply the plant with nitrogen, and

make for a thriftier, more vigorous growth, especially in soil low in this element. Whether the grower must supply this organism artificially by inoculating either the seed or the soil, is an ever recurrent question. We know that its presence is necessary for the best growth of the alfalfa. Without it the alfalfa plant must, like non-leguminous plants, depend on the nitrogen present in the soil, often too meager for the best results. On the other hand, the organism that produces the nodules on alfalfa and on bur clover are apparently identical and interchangeable; and since bur clover is so widely distributed throughout California, probably relatively few soils are without an abundance of the organisms. Rarely, in fact, does a field of young alfalfa fail, in the spring to show a good supply of nodules. Evidence is, unfortunately, still insufficient to enable us to say definitely under what conditions it may or may not be necessary to inoculate. Most of the tests made by farmers have, to be sure, given negative results, but in numerous cases inoculation has proved beneficial. These facts make inoculation seem wise, especially if the land is being seeded to alfalfa for the first time, unless the grower knows from past experience in that particular section that it is unnecessary.

Three methods of inoculating alfalfa have been employed: the use of soil, the use of a soil solution or suspension, and the use of pure cultures. By the first method, 150 to 200 pounds of soil taken from an old field is scattered over each acre of the new field and worked in just prior to seeding. This method is effective, but entails considerable labor and has other disadvantages; it is now used but little. Under the soil-suspension method, which is cheap, effective, and easy to use, 100 pounds to 200 pounds or more of soil is mixed in a barrel or vat with two or three times its volume of water. The mixture is allowed to stand for a few days in a warm place, out of the direct sunlight, with an occasional stirring. Then, after the soil has been allowed to settle out, the clear water solution is dipped off and used for treating the seed. The seed should be spread in the shade on a clean floor or canvas, and sprinkled with the water solution until thoroughly wetted. The seed when dry is immediately planted. The principal objection to the soil-suspension method is the danger of introducing into the new field the organisms of such diseases as crown rot and bacterial wilt. The method cannot be recommended, therefore, unless the grower is certain that the field from which the soil was obtained was free from serious alfalfa diseases. In no case should the method be used in sections where the above diseases are known to exist.

Pure cultures are commercial preparations of the nodule bacteria, put up in various media, and appearing on the market under different trade names. If used while still in a fresh condition and strictly according to directions, the commercial culture will usually give very satisfactory results. Unfortunately such cultures deteriorate rapidly and often reach the purchasers in poor condition. In no case should they be kept for any length of time before using. While the commercial cultures are more expensive to use than the soil suspension, and, in some cases at least, less effective, they do eliminate the danger of introducing diseases into the new field. The increasing prevalence in the state of a number of serious alfalfa diseases which might be spread by the inoculation medium, makes the commercial cultures the safest method to use when inoculation is necessary.

CULTIVATION AND IRRIGATION

Care of the New Seedling.—If the field were free from weeds, the seedbed in good condition, and the weather favorable after seeding, no attention, save perhaps one or two irrigations, might be needed until the plants reach the blooming stage. As a rule, however, conditions are not so favorable. The vagaries of the weather, the prevalence of weeds, and other factors usually make some attention necessary.

Drying winds after the crop is sown will often remove the moisture so rapidly from the surface of the soil as to seriously endanger the germination of the seed. Going over the field with a corrugated roller will press the seed more firmly into contact with moist soil, and will greatly reduce the loss by evaporation. Light soil can usually be advantageously rolled after seeding. Heavy soil should be rolled only if the seedbed is open and loose and in danger of drying out too rapidly, for if rolling is followed by light rain, the surface is likely to crust so badly that the tender seedlings cannot push their way through. In fact, crusting of the surface before the seedlings become well established is one of the most common difficulties encountered on the heavier soil, especially with spring seeding. If the seedbed has been too finely pulverized even a light rain may cause it to run together to such an extent that most of the seedlings will be smothered. Sometimes the surface can be broken sufficiently with a roller or a harrow, but more often it is so tenacious that reworking and reseeding are the only feasible procedures.

If the crusting or baking of the soil occurs after the seedlings have emerged, but while they are still tender, the stand can often be

saved if the soil is kept moist by repeated light irrigations until the roots are well developed, and the plant has attained one or more pairs of permanent leaves. After this stage is reached, the plant is fairly hardy and able to stand considerable adversity.

Annual weeds of one form or another always appear to some extent in every new alfalfa field. Because of their rapid growth, they may, when very numerous, seriously threaten the new stand by their shading and smothering effect. Since they cannot be cultivated out, the only way of combating them is to cut them back with a mower, and thus again expose the slower-growing alfalfa plant to the air and sunlight. The fact that a weedy field will, if clipped back, do much better than one not clipped, has doubtless been responsible in part for the popular belief that clipping back the young alfalfa when it has reached a height of 8 to 10 inches will cause it to stool out and do better than if it is left unclipped. The practice is general even in the fields fairly free from weeds. Experiments have amply demonstrated, however, that clipping is not good for the alfalfa but may in itself be a factor in thinning the stand and slowing up growth. During the early stages of growth, the alfalfa plant is usually slender or spindling, with most of the leaves near the top. If it is cut off low enough so that all the leaves are removed, it will die. If only a few leaves remain, its growth will be checked. The most vigorous plants are those allowed to pursue their normal course until they are well in bloom, when new, vigorous buds appear at the base, and the new growth is ready to function. The old growth can then be removed with impunity. In clipping even weedy fields one should, therefore, cut off the growth several inches above the ground, so as to disturb the young alfalfa plants as little as possible.

Irrigating Young Alfalfa.—How frequently should young alfalfa be irrigated? There is much difference of opinion on this point and but few actual facts. Many growers, believing that irrigation should be withheld until the plants show a positive need of water, do not irrigate until wilting occurs. The theory behind this practice is that withholding water will force deeper root development, so that the plant will have a larger feeding area and hence make a larger growth later. Within reasonable limits this view has perhaps some justification. If the surface of the soil is kept saturated, root penetration will be retarded; but there is no good reason to believe that it will develop most rapidly if the plant is actually suffering for lack of water. A field that is irrigated earlier and often enough to maintain a normal rate of growth will produce more of a crop the first season—

a fact worthy of consideration, especially when the stand at best lasts but a few years.

Irrigating Old Fields.—After the crop has been established and the first cutting made, a normal routine with regard to irrigation begins which is followed throughout the life of the field. The time and frequency of irrigation, as well as the amount of water applied, are governed to some extent by the idiosyncrasy of the grower, but also of necessity by the character and physical condition of the soil. The most common practice on deep loam soil of good moisture-holding capacity is to irrigate once per cutting, usually as soon as the hay crop has been removed. After cutting is the easiest time to irrigate, for then there is nothing to obstruct the flow, and the course of the water over the field can be easily watched and controlled. Some growers, however, prefer to irrigate a week or ten days before cutting, regulating the time so that the surface of the soil will be dry when the crop is to be cut. The advantage claimed is that there will be sufficient moisture in the soil to continue growth immediately after the crop is cut. As a matter of fact, fields thus treated will usually show a vigorous new growth before the hay crop is removed, while fields handled by the former method will usually show little or no growth until after water is applied. In addition, danger of scalding is materially reduced. On the other hand, unless the field has been very well leveled, it is difficult to get the water evenly distributed, since its course over the field cannot be so readily observed.

On light soil of low water-holding capacity, or on soil into which the water does not penetrate readily, two or more irrigations per cutting may be necessary. The most desirable practice in this regard must be determined by the grower himself. When the plants lose their lush, succulent appearance and take on a dark green color, it is a good indication that more water is required.

Experiments have shown that 2½ to 3 acre-feet of water per season is the optimum amount for alfalfa for most sections of California. This is equivalent to about 5 to 6 acre-inches per cutting. Quantities greatly in excess of these amounts resulted in reduced yields. Much of the alfalfa in California gets more water than it needs and in many cases enough to be decidedly harmful.

Care of Established Fields.—Under favorable conditions a field of alfalfa may thrive and continue to produce satisfactory crops without any attention except irrigation. More often, however, after

the field is a year or two old, the stand begins to thin out, weeds appear, especially in the spring crop, and the field may develop spots on which the growth is short and poor. What is the cause of these conditions, and what are the remedies? For want of information these questions cannot be fully answered at this time, though some of the causes are known.

While many alfalfa fields suffer from too much water, insufficient water, due to poor penetration, is also the cause of low yields in numerous instances. Many of our loams and heavier soils have a tendency to tighten up under continuous irrigation, so that it ultimately becomes difficult to get the water to penetrate deep enough to maintain normal growth except for very short periods. The penetration in many cases is so poor that if a normal application is applied a large portion of it must be drained off in order to avoid scalding the plants. One way to overcome this condition is to irrigate heavily during the winter and early spring while the soil is still moist, and while there is little danger of scalding. More frequent irrigations during the growing season, so that the soil is never allowed to become thoroughly dry, will also, as a rule, prove beneficial.

Thinning of the stand results from natural competition between the plants. In a new seeding, a much larger number of plants appear than can be supported when they attain full growth. The weaker plants are, as a result, crowded out. Under good conditions, however, the thinning should not reduce the plant cover or the yield, for the remaining plants should spread out and occupy the space of those that died. Further thinning may result from other causes, such as unfavorable soil and moisture conditions, diseases, plant injury, and too frequent cutting.

When the stand has thinned, the vacant spaces that appear are naturally occupied by weeds and grasses. The common belief that weeds and grasses come in and crowd out the alfalfa is, to say the least, only in part true. Such weeds as foxtail (*Hordeum murinum*) and other annuals probably do not cause thinning, but appear rather as a result of thinning. A good, healthy alfalfa plant is too vigorous to be easily crowded out. Furthermore, when the stand remains good, weeds are not such a serious factor, although they do appear in the spring crop. Such perennials as Bermuda and Johnson grass may offer sufficient competition to be a factor in thinning stands, especially if the plants are weakened from some other cause.

Weeds cannot be controlled completely. Some relief, however, can be obtained by proper winter cultivation, which many farmers now practice. Their frequent lack of success results mainly from failure to do the job thoroughly. The best implement for cultivating or renovating alfalfa is a renovator or a spring-tooth harrow, but once over the field with either implement is not enough to do much good. For the best results the cultivation should be given in the winter, after the weeds have made some growth, and the field should be gone over several times, if necessary, until all the weeds are dug out. Only in that way is the treatment effective.

Cultivation is not an unmixed blessing; some alfalfa plants will be pulled out or destroyed, and many others will be wounded. These wounds provide a ready means of entrance into the plant of the organisms of disease, so that in sections where diseases such as crown wart or bacterial wilt are prevalent, the cultivation may be an important factor in their spread.

Poor spots, when they appear in the field, are usually due to some soil troubles. Most often the soil is hard and compact, and does not take water readily. This condition may result from failure to break up the plowpan, from too much packing when the field was leveled, or from low spots where the water has accumulated and caused sedimentation and baking. There may also, in some cases, be an actual change in the physical condition of the soil after leveling and irrigation. In an established stand, little can be done to overcome the trouble. Subsoiling will sometimes help, but on some soils it will not, or the result will be only temporary. The most effective remedy, in most instances, is to apply in the winter a heavy dressing of well-rotted manure, which not only has a stimulating effect on the alfalfa but may also improve the penetration of the water.

The Use of a Companion Crop.—A common practice with many farmers is to sow oats or barley in the alfalfa in the winter at the time of renovation. The result is that the first cutting in the spring is a mixture of alfalfa and grain hay, the grain taking the place, in part, of the usual weeds. As far as the alfalfa is concerned, this practice seems unobjectionable: the competition from the grain should be no more severe than the competition from the weeds. The cereal materially increases, in addition, the yield of feed from the first cutting. Many farmers report failure to secure a stand of grain when seeded in alfalfa, the cause in most cases is the same as in the failure to secure satisfactory control of weeds by winter cultivation—i.e., improper cultivation. If the field is worked up thoroughly so as to

destroy the weeds and provide a good seedbed, and if oats or barley seed is sown at the rate of 40 to 50 pounds per acre and harrowed in, a satisfactory stand will normally result.

Another practice that has come into use in some of the dairy sections is to sow Sudan grass in the old alfalfa stand after the first cutting. After the first crop of hay has been taken off in the spring, the field is irrigated and worked up with a spring-tooth harrow; then Sudan grass is seeded at the rate of 15 to 18 pounds per acre and harrowed in. The cuttings throughout the remainder of the summer are a mixture of alfalfa and Sudan grass. In all cases, the subsequent hay crops are cut when the alfalfa reaches the proper stage of growth. Many dairymen report satisfactory results with this mixture, for the Sudan not only increases the amount of feed produced, but adds variety and succulence to the ration.

Longevity of Stands.—The productive life of alfalfa fields in California varies greatly. Many fields in the state 12 to 15 years old or more are producing fairly good crops. On the other hand, fields in many sections start to deteriorate after the second or third year, and by the end of the third or fourth stands are so poor and weedy that they have to be plowed up. This latter condition seems to be more pronounced in the older, more intensely farmed alfalfa districts, where it has become a matter of considerable concern. The general contentions of the grower are that the land is worn out for alfalfa, that the alfalfa has exhausted some constituent in the soil necessary for its growth, or that the land is becoming 'alfalfa-sick,' as has been the case with clover in the east.

There is no denying that in many parts of the state, alfalfa stands do not last so long as they should, nor do they last so long in most cases as did the virgin stands. The causes for this situation are for the most part unknown. Short life appears to be most pronounced on land which has been cropped intermittently to alfalfa for a considerable period, and may be due in part to the lack of proper rotation. Possibly, furthermore, nutritional disturbances may be a contributing factor; but fertilization as usually practiced does not offer relief. A partial survey indicates that the alfalfa troubles in some localities may be due to as yet unknown diseases, which are now being studied. In other localities, no apparent disease trouble has been found, but the shortest-lived fields are usually observed to be those which receive excessive irrigation. This would indicate that the attempt to secure maximum production by frequent and excessive irrigation might hasten the destruction of the crop. Still another

factor which is apparently contributing to the short life of the stand is too early cutting. In order to secure a better quality of hay, growers have tended to advance the time of cutting, until at present much of the alfalfa is cut in a very immature stage of growth. Field observations have indicated that fields that reach an advanced stage of growth before being cut last longer than those continually cut while immature. Investigations are now under way to discover if possible what part each of these factors plays in determining the life of the stands.

In the last analysis, the length of time which a stand should remain in order to be most profitable will obviously vary with conditions. The man who makes a busines of growing hay for market would no doubt wish that the field maintain a high state of productivity indefinitely. On the other hand, for the man who is growing the alfalfa in rotation with other crops, a few years of high productivity might suffice. Observations have rather definitely determined that even under good conditions, a field reaches its maximum production the second, third, or fourth year, and then starts to decline. Though the decline may be very gradual, the field is rarely profitable for more than 6 to 8 years.

MAKING ALFALFA HAY

The art of making a good quality of alfalfa hay can be acquired only with experience. Although certain general rules may be followed, the details of the process vary so much with temperature, humidity, season, etc., that specific directions cannot be given to fit all conditions. The grower should keep in mind the factors that constitute quality, and aim to handle his crop so as to attain the ideal as nearly as possible. Good alfalfa hay should be fine-stemmed, leafy, green in color, and free from weeds, grasses, or other foreign material. If the field is free from weeds and the stand good, so that the growth is not coarse, hay of good quality can be produced, provided the crop is cut at the right stage and properly cured.

Time of Cutting.—In determining the time or stage of growth at which to cut, the grower must consider not only the quality and value of his product but also the effect of the stage of cutting on the welfare of the field itself.

The highest quality of hay, the so-called 'rabbit-hay,' can be obtained only if the crop is cut in the early bud stage or some time before the plants begin to bloom. At this stage the stems are soft, immature, and pliable, and the plants are leafy. If properly cured,

an excellent, fine-stemmed, leafy product can be produced. As the plants grow older, the stems become coarse and the proportion of leaf to stem decreases; hay made from such older plants does not command so high a price on the market.

On the other hand, evidence is accumulating to show that the continuous cutting of rabbit hay is very bad for the field, and is one of the chief causes of the short life of the stands. Continuous early cutting also, as a rule, means rather low yield because the most rapid increase in weight of the plant occurs about the blooming stage. If the crop is cut when the plants are about one-tenth in bloom, the product will not bring so high a price on the market; but the difference in price will in most cases be more than offset by the greater yield. Cutting at this stage is, furthermore, not so injurious to the vigor and life of the plants. All things considered, therefore, the best stage to cut is when the plants are about one-tenth in bloom. Certainly this is true for the grower who feeds most of his hay; the slight difference in quality will be more than offset by the difference in the yield and the longevity of his fields.

As our western market particularly demands the softer, more succulent type of hay, many of the market-hay growers will doubtless continue to feel justified in attempting to reach the rabbit-hay market even at considerable sacrifice in yield and stand. To meet their difficulty, experiments are now under way with a view to finding some method of procedure which will permit the market-hay grower to cut most of his crop at least in the rabbit-hay stage, and at the same time increase his yield and the longevity of his stand. This information is, however, not yet available.

Curing and Baling.—The leafiness and color of the hay are determined largely by the method of curing, and this in turn is affected largely by local temperature and humidity conditions. Excessive handling when the hay is dry will cause the loss of leaves by shattering, while undue exposure to the direct sunlight will result in excessive bleaching.

The hay, once cut, should be left in the swath only until it is thoroughly wilted, but not until the leaves become dry and brittle. It should then be raked into small, compact windrows for further curing (fig. 2). The time which the hay may be left in the windrow depends upon the subsequent procedure. If the grower desires to complete the curing process in the cocks, the hay is often cocked directly after raking, or at least is left in the windrows for only a few hours. To save labor, however, many growers prefer to stack or

bale direct from the windrow, in which case the hay must remain in the windrow long enough to attain the proper degree of dryness. Hay may be stacked safely when it has been cured to a point where the stem shows some toughness when twisted. It must be somewhat drier if it is to be baled direct; but, in either case, overdrying must be avoided. Hay permitted to lie in the swath until brittle will lose a large percentage of its leaves on handling, and will make a low-grade product. In addition, long exposure in the windrow will result in excessive bleaching of the hay and in reduction of its value.

Fig. 2.—The side-delivery rake makes narrow, well aerated windrows in which rapid curing takes place with little bleaching or leaf shattering.

The exact procedure to follow will vary with the season and the locality. The high temperature and low humidity which prevail during the haying season in most sections of California, however, make for rapid curing and necessitate rapid handling. In some sections it is common practice to cut in the forenoon, rake into windrows in the afternoon, and stack or bale the following morning. In other cases, cutting is done in the afternoon, the hay is raked the following morning, and stacked or baled in the forenoon of the third day. Frequently, however, more time than this is necessary for curing. The details of procedure must be worked out for each specific locality.

Growers of market hay disagree considerably as to the relative merits of stacking hay before baling, or baling direct from the windrows or cock. The general inclination seems to be toward the latter,

mainly because of the saving in labor and expense. Hay of high quality can be produced by baling from the windrow direct, but careful attention must be given to details. Hay to be baled must be drier than is necessary if it is to be stacked, for too much moisture will cause the bale to heat and mold. On the other hand, it must not be too dry; otherwise the leaves will shatter badly, and the stems will become brittle, producing a coarse, harsh, stemmy hay. At the height of the haying season, in many sections, baling can be done only in the early morning or late afternoon, and the whole haying operation must be regulated to meet the capacity of the baler during this period.

Stacking the hay before baling has many advocates and many advantages despite the fact that it requires extra labor. Hay may be stacked with somewhat more moisture than is safe for baling. It can therefore be handled in a tougher condition, with less danger of loss of leaves by shattering. With modern equipment, large quantities can be handled in a short time. This fact may be of considerable importance when the areas to be handled are large. In addition, hay which is stacked for a few weeks goes through a sweat which increases its aroma, improves its palatability, and imparts a softness and pliability not obtainable in any other way.

Artificial dryers, which have recently appeared on the market, dry the green alfalfa to hay condition in a few hours, and some interest has been shown in their use in California. Although such a process undoubtedly results in a very superior product, its economic value for this state may be questioned. In the first place, the costs of installation and of operation are high, and it is extremely doubtful whether the hay thus produced would bring a price sufficiently higher than that of good field-cured hay to justify the expense. The weather conditions in California during the greater part of the haying season are so nearly ideal that with proper care a very excellent product can be produced by natural methods with very little danger from weather damage. On the other hand any expedient that would hasten curing without greatly adding to the cost of handling would be a welcome addition to our haying practices.

Storage of Alfalfa Hay.—Exposure to the weather is the chief cause of deterioration in alfalfa hay after it is harvested. Rain-soaked hay molds and spoils, or becomes musty and unfit for feed. Even though subsequently dried, it loses its color, its aroma, and much of its palatability. Rain also greatly reduces the feed value by leaching out considerable quantities of the mineral and protein constituents. Undue exposure to sunlight will cause the hay to become discolored

and less palatable. Whether the hay is to be fed on the farm or sold, it should be protected from the weather until it is disposed of, particularly if it is to be held through the rainy season.

Hay sheds or barns to which the hay can be hauled as soon as it is cured are the ideal places of storage, for hay is then fully protected from both rain and sun. Such structures are, however, expensive and not always obtainable. Under the next best method, stacking in the open, but little loss need occur if the work is properly done. The stack should be well made and, if it is to stand through the rainy season, should be covered with straw or grass hay that will shed the water readily. If the hay is later to be baled and sold, the bleached outside layer of the stack, together with any wet or spoiled hay, should be removed, for its inclusion in the bales may spoil the sale of the whole lot.

Some farmers who own their own baler, bale the hay in the field as it is cured and then store the bales in the barn or in open sheds. Thus they can store a much larger quantity of hay in a limited space than by handling loose. When the hay is to be marketed later, the practice is very commendable. Whether or not the saving in hay and labor will justify the cost of baling when the hay is all fed on the farm is a question that each grower must answer for himself.

The practice of chopping alfalfa hay is increasing, since even with coarse hay, it eliminates all waste when it is fed, the saving thus made often amounting to 25 per cent or more. A few farmers chop the hay directly as it is hauled from the field and blow it into the barn or mow. The advantages claimed for this procedure is that it reduces the cost of handling and enables them to store a larger quantity in a limited space because the chopped hay is less bulky than the loose hay. The practice is unquestionably a good one if due precaution is taken to prevent heating. Chopped hay heats more readily than loose hay, so that the hay that is to be chopped must be drier than would be necessary for handling in the usual way.

MARKET GRADES OF ALFALFA HAY

From the grower's point of view, the system of grading alfalfa hay now in use in California is not wholly satisfactory. In the first place the grades are indefinite, varying not only with the market demands but also in the different markets, and to a greater or less extent among dealers in the same market. For this reason the grower can have but a very general idea of how his hay will grade, or of what it will be

worth. If a grower has marketed his hay through the same broker for a number of years, he will, to be sure, have gained a pretty definite knowledge of the wants of that particular broker, and of the grading of any given lot of hay; but should he for any reason find it desirable to change his market, he might find it necessary to revamp his whole idea of grades.

Secondly, the grades at present are determined entirely by one party to the transaction, i.e., the buyer; and, justly or not, the farmer cannot help feeling that he is getting the worst of the bargain. What is needed is a set of grades definite in their nature, and determined by a party disinterested in the transaction. Such grades have been promulgated by the Bureau of Agricultural Economics of the United States Department of Agriculture. Their adoption under the supervision of the Federal or State Department of Agriculture would at once do away with present indefiniteness, uncertainty, and suspicion. Some objections have been raised to the adoption of the Federal grades, especially by the hay dealers, who are loathe to depart from established practices. In the long run, however, the change would undoubtedly benefit all concerned. These grades have now been in force for some time in two of the larger hay markets in the country—Chicago and Kansas City—with entire satisfaction, and there is no good reason why the same should not be true in California.

TABLE 4

FEDERAL GRADES FOR ALFALFA HAY

Class requirements		Grade requirements			
Class	Mixture	U. S. grade	Leafiness of alfalfa (per cent of leaves)	Per cent green color	Mixture, per cent foreign material
Alfalfa	Alfalfa with not over 5 per cent grasses	1	40 or more	60 or more	5
		2	25 or more	35 or more	10
		3	Less than 25	Less than 35	15

The Federal grade for 'alfalfa and alfalfa mixed hay' consists of ten different classes, the class being determined by the nature and the amount of the mixture. Only the grades for the class 'alfalfa' are included here. In addition to the three full grades, a number of subgrades are recognized. Thus hay in which the leafiness if more than 50 per cent would be designated as 'extra leafy' or more than 75 per cent was green in color, would be designated as 'extra green.' The grades, therefore, would read 'U. S. No. 1 extra leafy alfalfa,'

or 'U. S. No. 2 extra green alfalfa,' as the case might be. Similarly alfalfa in which more than 30 per cent of the stalks were unusually coarse would have the word 'coarse' included in the grade designation. In addition, hay which for one reason or another cannot be placed in one of the fixed grades is designated as 'sample grade,' and the reason therefor is given.[6] These grades have been in use long enough to demonstrate amply their adequacy under all conditions that may arise.

MEASURING HAY IN STACKS

Although the most satisfactory basis on which to sell hay is by weight, many local sales of stacked hay are made under conditions where it is inconvenient or impossible to secure the weight. Under these circumstances, some rule of measurement for approximating the number of tons in a stack must be used. A number of rules have been employed for estimating the tonnage of stacked hay, and all are fairly accurate under certain conditions. We should remember, however, that any rule is at best an approximation, for no two stacks will be exactly alike, either in their shape or in the density of the hay which they contain. The volume of hay required to make a ton is particularly subject to wide variation.

The 'United States Department of Agriculture Rule,' unquestionably the best for determining the volume of a stack, is as follows:[7]

$F \times O \times W \times L =$ number of cubic feet

where

$O =$ 'over,' measured from the base at one side over the stack to the base at the other side, in feet.

$W =$ width of stack in feet.

$L =$ Length of stack in feet.

$F =$ a factor determined experimentally from 9 different-shaped stacks. These can be divided into three groups based on relative height to width, and into three additional groups based on shape as viewed from the end, as given in table 5.

The mean factor, it will be noted, is 0.31, which appears three times in the tabulation; for average conditions, this factor may be used. For greater accuracy, however, the height and shape of the stack should be observed (fig. 3), and the proper factor used, as given in the table. After the volume of the stack in cubic feet has been obtained, this result is divided by the number of cubic feet in a ton to secure the tonnage.

[6] For further information on the Federal hay grades and their application write to the Division of Field Crops, State Department of Agriculture, Sacramento.

[7] McClure, H. D., and W. J. Spillman. Measuring hay in ricks or stacks. U. S. Dept. Agr. Office of the Secretary. Cir. 67:1–10. 1919.

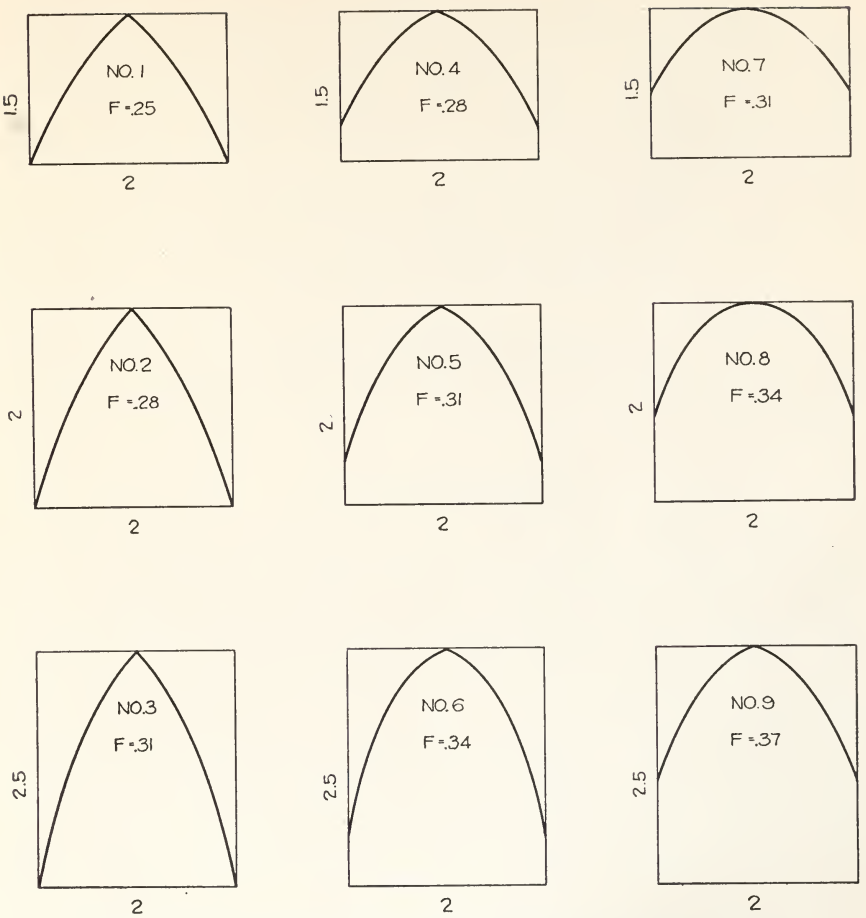

Fig. 3.—Cross sections of hay stacks of different shapes. (After McClure and Spillman.)

TABLE 5*

FACTOR (F) FOR VARIOUS SHAPES OF HAY STACKS
(U. S. Dept. of Agr.)

Relative height and width of stack	Shape of stack		
	Roughly triangular in shape	Medium full	Full and rounded
Height about ¾ as great as width	0.25	0.28	0.31
Height about equal to width	0.28	0.31	0.34
Height about 1¼ times width	0.31	0.34	0.37

* Adapted from : Stewart, Geo. Alfalfa growing in the United States and Canada, *p. 307*. Macmillan Company, New York City, 1926.

The number of cubic feet of alfalfa hay to the ton varies from 512 cubic feet just after stacking, to 422 cubic feet for hay that has been in the stack for several months. Between these figures the volume per ton varies, according to the length of time the hay has been stacked, about as follows:

Hay stacked 1–10 days—512 cu. ft. per ton
Hay stacked 20–30 days—480 cu. ft. per ton
Hay stacked 30–60 days—460 cu. ft. per ton
Hay stacked 60–80 days—440 cu. ft. per ton

If the stacks have been settled by heavy rain, the volume will be somewhat less. The moisture content of the hay, the time of stacking, and the fineness or coarseness of the stem will also influence the volume weight.

PASTURING ALFALFA

Alfalfa is used extensively in California for pasture, mainly because it is one of the few crops which will provide sufficient feed to justify the use of the land for pasture purposes. In addition to its high nutritive value, it will under favorable conditions carry a larger number of animals per unit area than any other crop, with the possible exception of Sudan grass.

Pasturing is not particularly injurious to alfalfa if it is done properly. The best practice is to divide the pasture into two areas so that one can be irrigated and allowed to make some growth while the other is being grazed. In no case should the crop be pastured while the soil is wet, for the tramping of the animals will cause the soil to puddle and become so hard that water penetration will be retarded and the growth checked. Pasturing while the soil is wet is also most injurious to the stand.

When two fields are pastured alternately, however, the growth should not be allowed to get too large before the stock are turned in otherwise a large part of the crop may be trampled down and wasted.

Too heavy grazing over long periods may cause the plants to be weakened, and the stand thinned prematurely, especially if growth is forced by frequent irrigation. If the field is dry and the normal rate of growth is slow, close grazing is apparently less injurious. Wherever possible it appears to be best to allow the field to mature a crop of hay occasionally, and this should preferably be done in the fall. This treatment will strengthen the plants materially, and the result in less dying out during the winter. Observations also indicate that fields which have been heavily grazed, especially in the late

fall, so that the plants go into the winter with little growth or in a weakened condition, will be much more heavily infested with foxtail and other weeds in the spring than will fields not grazed so heavily.

In the last analysis, it must be said that pasturing is not good for the alfalfa, but alfalfa is one of the best pasture crops we have and must be used for that purpose. Care should be exercised in handling the pasture so as to secure the maximum amount of feed and at the same time make the stand last as long as possible.

ALFALFA SEED PRODUCTION

The annual production of alfalfa seed in California is between 3 and 4 million pounds, while our annual consumption runs well over 5 million pounds. We could possibly increase our seed production with profit, but it is not advisable for anyone to embark in the industry on a large scale except in proved districts. Unfortunately less definite information is available on the production of alfalfa seed than on any other crop that we grow. We do know, however, that successful and profitable production of alfalfa seed requires a rather definite combination of conditions that obtain only in a few sections.

Most of the alfalfa seed produced in California is grown in two widely separated districts—the Hemet Valley in Riverside County, and the Cedarville District in Modoc County. Some seed is also grown in the Sacramento Valley, and small quantities in other sections; but the yields are usually low or uncertain. Just why certain sections will produce good crops of seed and others will not is unknown.

On some soil, alfalfa will make a rapid, luxuriant vegetative growth that will quickly exhaust the soil of its available moisture. After the moisture is used up, the alfalfa will wilt and, in extreme cases, turn brown. Good yields of seed can never be obtained under such conditions. On some other soils the plant is apparently unable to exhaust the moisture so rapidly, the growth of the alfalfa is, in consequence, dwarfed and stocky, but without the tendency of the plants to wilt or dry down. On such soil, with proper handling, under favorable climatic conditions, a good seed crop can usually be produced. In general, a proper combination of soil and moisture which will retard vegetative development to the proper degree is necessary; and while it is possible to approach this condition on many soils, to attain the requisites for good seed yield seems to be impossible on most soils.

Climate is also a factor. High temperatures and drying winds will prevent pollination and reduce seed setting. Many soils probably would produce a good seed crop except for the fact that the proper moisture conditions can be reached only at the time of year when temperatures or other climatic conditions are unfavorable. The right combination of the three is necessary for success.

Culture.—The cultural methods involved in growing alfalfa seed do not differ materially from those used in the production of hay, especially in so far as the preparation of the land and the seeding of the crop are concerned. In fact hay and seed production go together, since two or three cuttings of hay are usually obtained during the season in addition to the seed crop. It is not desirable to have so thick a stand as for hay, and where seed is the main object, a lighter rate of seeding is often practiced. In other cases a seed crop is not cut for the first year or two, or until the stand has thinned to some extent.

The main departure comes in irrigation and in the method of harvesting. As the water relation is all-important, special attention must be given to the amount and time of irrigation. Unfortunately this varies with local conditions, and the proper procedure can be determined only with experience. It should be emphasized, however, that the moisture must be reduced so that the growth of the seed crop is dwarfed, but not so much as to cause the plants to wilt or wither. In some sections the common practice is to irrigate heavily in the winter or early spring, so that the soil is well filled with moisture, after which no further irrigation water is applied until the seed crop is harvested. In this case one or two cuttings of hay are taken off and the next crop allowed to go to seed. On soil retentive of moisture, two hay crops are normally necessary to reduce the moisture contained in the soil sufficiently so that a good crop of seed will set.

In the Sacramento Valley some seed is grown on deep moderately heavy loam soils without any irrigation whatever. Here, however, the rainfall is fairly high, and it is usually necessary to remove two cuttings of hay, allowing the third crop to go to seed. In dry seasons the second cutting may be the seed crop, and this is also true where the normal rainfall is less, or on less retentive soil. On the irrigated land, if the soil appears to have become too dry for the best setting of seed, a light irrigation may be given, but it should not be heavy enough to wet the soil to any great depth.

Probably the question most commonly asked in connection with seed production is how to tell whether a given crop will be worth sav-

ing for seed. No definite way of determining this is now known. The general appearance of the field is the only guide. Heavy blooming is of course necessary, but heavy blooming does not necessarily mean a heavy set of pods. Even with a heavy bloom, if the temperature is too high, the setting of pods may be greatly reduced. The reason high seed yields are rarely obtained in the interior valley is probably that by the time the seed crop is in bloom, the temperature is too high for the best setting of pods. The nature of the vegetative growth must also be taken into account. The vegetative development should be dwarfed and dark in color, and the new shoots, which normally appear in abundance at the beginning of bloom, should be conspicuous by their absence.

Harvesting the Seed Crop.—The seed crop does not mature evenly; it is, therefore, impossible to mature and harvest successfully all the seed that has set. The pods, when ripe, turn dark brown or nearly black, and the seed is golden yellow. When fully mature, the pods shatter off easily, so that if the crop is allowed to stand until all the pods are brown, a considerable portion of those first ripe will be lost. It is usually necessary, therefore, to cut when about two-thirds of the pods are ripe. The immature seed from the pods still green will of course be of little value and must ultimately be removed, but this cannot be avoided.

As the pods shatter off easily, the crop should be handled carefully to avoid excessive loss. With present practices a very appreciable loss undoubtedly occurs from cutting to threshing. Some seed growers cut the seed crop with the ordinary mower, just as they would a hay crop, and then rake it into small piles with a hay rake. This is a poor practice, for much of the best seed will be tramped and shaken out. A considerable improvement on this method is to use a windrowing or bunching attachment on the mower. With such a device the machine or animals do not pass over the cut portion, nor is it necessary to handle it again until it is to be threshed. Probably the best machine for cutting the seed crop is the reaper which deposits the crop, as it is cut, in small bunches out of the way of the implement. The reaper involves less shaking and rough handling than any other machine. Early morning cutting while the plants are tough will shatter the crop less than cutting during the warm part of the day.

The crop, as soon as cut, should be placed for curing in small piles, no larger than can be conveniently picked up in one forkful at

loading time. When a reaper is used for cutting, further piling is often eliminated.

Because of the favorable weather conditions the crop may be left in the field until completely cured, and then hauled directly to the thresher. Many growers, however, stack the crop as soon as it is dry enough, and thresh when convenient. Stacking has the advantage that the product may be handled in a tougher condition with less loss of seed by shattering. Also by removing the crop from the field, the land can at once be irrigated and the next growth of hay started without delay. To haul the crop from the field, tight wagon beds should be used and racks covered with canvas, so that the shattered seed and pods are not lost.

The best machine for threshing alfalfa seed is the alfalfa seed huller. Many growers have used the ordinary grain thresher, which will do very good work if properly adjusted. The concaves must be set closer than for grain, and special alfalfa sieves must be provided. Unless the crop is very dry, the chaff and straw must sometimes be run through a second time so that all of the seed may be secured.

No matter what machine is used, the threshed product will contain immature and shriveled seeds and bits of stem and other foreign material, all of which must be removed before the seed can be used. Few growers are equipped to reclean alfalfa seed properly; the common practice is to sell it 'in the dirt,' the buyer or dealer taking the responsibility of recleaning and preparing it for market.

Yields of alfalfa seed are extremely variable. At least 250 pounds per acre is ordinarily considered necessary to pay expenses. The average under favorable conditions probably runs between 350 and 400 pounds, 600 pounds is a good crop, and 800 to 1000 pounds per acre is sometimes (but very rarely) obtained.

DISEASES OF ALFALFA

As a complete alfalfa-disease survey of the state has not been made, the actual number of alfalfa diseases present is not known. Only a few, however, are prevalent enough to cause great concern. The most important are leaf spot, crown wart, and bacterial root rot. Rust causes some damage, especially when the weather conditions are favorable for the disease, while bacterial stem blight (or Sackett's disease) and brown root rot have occasionally been reported.

Leaf Spot.—This disease is caused by the fungus *Pseudopeziza medicaginis,* and appears as brown spots about one-sixteenth of an

inch in diameter, on the upper surface of the leaf, and in severe cases may penetrate the leaf and cause spots to appear on the under side as well. The lower leaves of the plant are attacked first, turn yellow, and drop off. This leaf-pruning reduces the vigor of the plant and consequently the yield. Although the disease can be found at all seasons, severe damage occurs mainly in the spring. Fields badly infested should be mowed regardless of the stage of growth, and the crop removed from the field. The new growth is not so likely to be injured greatly. Withholding irrigation will also reduce the spread of the disease.

Crown Wart.—Crown wart is caused by the fungus *Urophlyctis alfalfae* and, as the name implies, appears as rough, irregular, gall-like swellings on the crown of the plant. Just how prevalent the disease is in California is not known. The damage which it inflicts on the crop seems to vary with conditions. Badly infected fields have been observed to produce very satisfactory crops. In other fields crown wart has proved to be very destructive, killing out large areas in a single season. It seems to be worst on very moist soils. The only known method of control is to plow up the stand and rotate for a few years with annual crops.

Bacterial Root-Rot.—This is a bacterial disease caused by the organism *Aplanobacter insidiosum.* Infected plants become dwarfed, and the cambium layer of the root just under the bark becomes yellow and discolored. In addition to the dwarf growth, the stems become fine and the leaflet small, the whole plant ultimately taking on a yellowish cast. The course of the disease under some California conditions is very rapid. It is usually manifest the second year, and by the end of the third year the stand may be seriously depleted.

Bacterial root-rot is a comparatively new disease and as yet but little understood. Its presence in California was first noted in 1925, and since that time it has been found in many fields, especially in the San Joaquin Valley. Since the disease can be spread by hay and litter, machinery, and irrigation water, it will probably be found, a few years hence, in practically all alfalfa-growing sections of the state. Because of its ease of dissemination and its virulence, it is without question the most serious alfalfa disease with which we have to contend at the present time. Rotation of crops is the only remedy that can be suggested for its control. Apparently alfalfa and sweet clover are the chief hosts for the organism, but it will live on some other clovers and possibly also on bur clover. During the period of rotation, therefore, all legumes of this nature should be eradicated.

Just how long the organism will survive in the soil is not known, but alfalfa should not be seeded on the land again for at least four years.

Other Diseases.—Rust sometimes appears after late spring rain, especially if the weather is warm and the humidity high. It rarely does much damage to the hay crop but may cause serious injury to the seed crop. If a severe attack occurs early in the growth period, or before the seed pods have started to form, the crop should be cut for hay and removed from the field. In most cases the next cutting will suffer but little from the disease.

The bacterial stem blight has been observed only in a few cases, causing some injury to the spring crop; later crops usually do not show any serious effects of the disease.

The brown rot caused by the fungus *Ozonium auriconum* has been reported from the southern part of the state, though little is known as to the extent of the disease or its destructiveness. In infected fields the plants begin to die in spots, which rapidly enlarge as the disease progresses. Rotation is the only method of control, but the rotation should consist largely of grasses such as cereals, corn, and sorghum, for many plants besides alfalfa serve as hosts for the disease.

INSECT ENEMIES OF ALFALFA

Of the insect enemies of alfalfa the three most important are grasshoppers, alfalfa caterpillar, and aphis. Other insects attack alfalfa, but rarely in sufficient number to cause much damage.

Grasshoppers.—Grasshoppers are a common and ever present pest of alfalfa and other field crops. While the damage done by these insects every year is in the aggregate large, only occasionally do they appear in sufficient numbers to be really destructive to the crops. These destructive outbreaks ordinarily follow mild winters which have permitted a large percentage of the eggs to escape destruction. The adult grasshopper deposits her egg in the ground in the fall one or two inches below the surface. From 30 to 100 eggs are deposited in each burrow. The hoppers hatch in the spring and feed voraciously throughout the summer months.

Cultivating all waste land such as ditch banks, fence rows, and roadsides during the winter has been recommended as a means of preventing the outbreaks. Although the cultivation of such waste land is a good practice for other reasons, it is of questionable value as a means of reducing the number of grasshoppers, even when conscien-

tiously carried out by a whole community. In most parts of California vast areas of land not subject to cultivation serve as excellent breeding grounds for grasshoppers, from which they can readily migrate to the cultivated areas. The cultivation of the waste land on farms consequently can have but little effect on the total number of insects. Some species, however, like the differential grasshoppers, live and breed in the alfalfa fields and the suggestions given above often prove effective in keeping them under control.

The most effective means of control when the swarms appear is poison bait, which can be made by thoroughly mixing 100 pounds of bran, 3 to 4 ounces of sodium arsenite, 2 gallons of cheap molasses, and ½ dozen finely chopped lemons. After mixing, sufficient water should be added to produce a moist, but not wet or soggy mash. This bait is scattered around the edge of the field, or even over the field if the crop has just been removed. Poisoning is most effective as soon as the grasshoppers appear, for the young hoppers are more easily killed than the adults. On fields which have been badly infested, the number can be effectively reduced by the use of the hopperdozer.

Alfalfa Caterpillar.—Like the grasshopper, the alfalfa caterpillar is always present, but only in limited areas or during especially favorable seasons does it appear in sufficient numbers to threaten the crop seriously. The caterpillar is the larva of the sulfur-colored alfalfa butterfly, commonly observed around alfalfa fields. The insect passes the winter in the pupa stage, attached to the stems of alfalfa or other vegetation. The adults emerge in the early spring, eggs are deposited, and the larvae appear in May or June. Two or three broods may occur during the season.

When the caterpillars appear in large numbers, the crop should be cut at once and removed from the field. In this way the larger proportion will be prevented from completing their life cycle. If the field is then cultivated with a disk and harrow, or alfalfa cultivator, many of the pupa as well as the larva that have fallen to the ground will be destroyed.

Since the pupae pass the winter attached to stems of alfalfa and other vegetation, the removal of all old vegetation from the field and surrounding areas will aid in preventing serious outbreaks in the spring.

Aphis.—In the southern part of the state where the winters are mild, aphis frequently cause great damage to the spring crop. New seedlings are also attacked and may be destroyed or the stand greatly

reduced. Numerous methods for destroying the insects on the old stand have been used with fair success in some cases. Removal of the winter growth by mowing, or better still by heavy winter pasturing, is probably on the whole the most practical method. While such treatment is not particularly good for the alfalfa, no great harm will be done if the fall growth is not forced too much with late irrigation.

The danger to new seedlings may be avoided by making the conditions for growth as favorable as possible and by frequent irrigation. Calcium cyanid scattered over the field at the rate of 25 to 50 pounds per acre has also proved effective in the destruction of the aphis while the alfalfa is small.

ANIMAL PESTS OF ALFALFA

The only animal that causes much damage to alfalfa in California is the pocket gopher,[8] prevalent in all alfalfa-growing sections of the state. On fields irrigated frequently by flooding, it usually does not cause much trouble except on the levees, in the ditch banks, and in the areas surrounding the field. The greatest damage is done on the unirrigated fields or on fields irrigated infrequently.

The gopher burrows under the ground and gnaws off the roots of the plants, which subsequently dry up and die. In addition, the mounds of soil which the rodents throw up interfere with the harvesting of the crop.

The best means of control is by trapping or poisoning. Poisoning is particularly recommended when large numbers of gophers are present. Small pieces of apple, carrots, sweet potatoes, or raisins into which a small quantity of strychnine sulfate has been thrust have been used with success. This bait is placed in the fresh burrow. The field should be gone over repeatedly, and poison placed in all fresh burrows as soon as they appear. Carbon bisulfid has, in many cases, been successfully used.

COST OF PRODUCING ALFALFA

Unfortunately accurate information on the cost of producing alfalfa in California is not available, for but few comprehensive cost studies have been made. With conditions as varied as they are in this state, we would naturally expect to have wide differences in costs. Even on different farms in the same section, differences in methods

[8] See: Dixon, Joseph. Control of pocket gophers in California. California Agr. Ext. Cir. 29:1–16. 1929.

of handling and differences in yield may cause the per-ton cost of products to vary greatly.

Any consideration of the cost of producing alfalfa naturally divides itself into two steps: (1) the cost of preparing the land and getting the crop started and (2) the cost of harvesting the hay crop after the field is established.

In preparing raw land for alfalfa, the most expensive items are leveling and checking for irrigation, and, in some cases, the development of the water supply itself. The cost of leveling and checking varies between wide limits, depending on the lay of the land, on the size of the checks, and particularly on the amount of the soil that must be moved. Certain areas can be prepared for irrigation for as little as $25 an acre, while other areas may run as high as $100 an acre or more. The average for all sections is probably close to $50. Where water is to be supplied from wells, the development of an adequate water supply may cost from $50 to $100 per acre more. Putting the land under water is, of course, a permanent improvement and enhances the value of the property, but as water is essential to success with alfalfa, a considerable outlay of capital may be necessary before the crop can be grown.

The cost of preparing the seedbed, of seeding (including the cost of the seed), and of caring for the young crop should not exceed $10 an acre on an avereage.

After the field has been established, the per-ton cost of production is also subject to wide variation, owing not so much to difference in the cost of labor as to difference in the cost of handling, the cost of water, and the yields per acre which are obtained. The schedule following is, therefore, presented merely as a guide rather than as a statement of actual costs under any given conditions. Labor is calculated at $3.60 a day, and horses at $0.75 a day.

The per-ton cost of production of $8.04 as here given is without doubt considerably below the average for the state as a whole, largely because only two and one-half feet of water are allowed—the amount actually needed under good conditions to produce the crop. Most growers, as a matter of fact, use much more than is actually needed.

In many cases, also, the cost of water is higher than here given, especially when it is pumped from deep wells. Lastly, as already indicated, a lowering of the yield causes a rapid increase in the per-ton cost of producing, for many of the items remain practically the same regardless of the yield obtained. According to the above figures, if the yield were only five tons per acre, the cost would be $9.80 a

ton. The limited studies made have shown actual production costs as low as $6 a ton on some farms, but more than $15 a ton on others; apparently the chief factors in this wide variation in costs were differences in yield and in cost of irrigation.

TABLE 6

COST OF PRODUCING ALFALFA IN ESTABLISHED FIELDS

Operation or expense	Amount of work per day	Men and horses required	Cost per unit	Cost per acre
Winter disking or cultivating	6 acres	1 man, 4 horses		$1.10
Mowing*	8 acres		63 cents a cutting	3.78
Raking*	16 acres		31 cents a cutting	1.86
Shocking			50 cents a cutting	3.00
Irrigation water (2½ acre feet)			$2.00 an acre foot	5.00
Irrigating				4.00
Baling from the stack‡			$3.50 a ton	21.00
Hauling			1.00 a ton	6.00
Taxes				2.50
Total cost				48.24
Cost per ton				8.04

* Based on 6 cuttings at 1 ton per cutting.

‡ Baling from stack $3.00 a ton, to which must be added $0.75 a ton if the crop is stacked in the field with buckrakes and stacker, or $1.25 a ton if it is hauled from the field with wagons.

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