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ALFALFA.

Alfalfa in the Southwest

By Geo. F. Freeman

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Tucson, Arizona.

PREFACE

In that chapter of Les Miserables describing the sewers of Paris, Victor Hugo, writing in 1862, attributes the impoverishment of France to unrestored losses from her agricultural soils. The costliest and most vital of these losses is nitrogen, an essential constituent of protoplasm, to which the activities of all living plants in large part must be referred.

Guided by the teachings of Liebig and other pioneers in agricultural chemistry, the farmers of Europe sought to restore these losses by means of fertilizers; and a great trade in guanos, nitrates, and manufactured composts was developed for the purpose of maintaining the productiveness of cultivated soils. But the guano islands are now stripped of their rich accumulations, the nitrate beds are approaching exhaustion, and home-made fertilizers remain inadequate to the maintenance of fertility.

Processes have therefore been devised for the manufacture of compounds from the inexhaustible nitrogen supply of the air, amounting to nearly eight tons of this element for every square yard of the earth's surface. Cyanamid, calcium nitrate and aluminium nitride, resulting from three such processes, are the most important substances thus far produced for this purpose. These compounds, however, require excessive amounts of electric energy for their manufacture, and as yet can be produced commercially only under the most favorable conditions.

Meantime, several species of soil bacteria have been discovered which have the power, some to build up and others to destroy, useful compounds of nitrogen in the soil. Finally, in 1886, Hellriegel observed that certain bacteria living in the roots of peas and lupines fixed atmospheric nitrogen; and this has since been found to occur in the roots of all leguminous plants, including alfalfa. Leguminous plants, therefore, are a means by which, during the production of profitable crops, we may add nitrogen to agricultural soils without the heavy outlay for commercial fertilizers otherwise necessary. It is of interest m this connection to recall the compensating fact, that a very high proportion of native Southwestern plants is leguminous, about 300 out of 3000 species in Arizona belonging to this family. These native legumes in our nitrogen-barren, desert soils are, doubt-

less, in Nature as in agriculture, beneficial to associated species, and significant groups of leguminous with non-leguminous species are common. Similarly, alfalfa, which is exquisitely adapted to climatic and cultural conditions in the Southwest, contributes nitrogen supplies needed for the growth of other crops in our arid soils.

In estimating the fixation of nitrogen by alfalfa we may assume that two-thirds of the nitrogen in the hay crop comes from the air. On this assumption an annual product of ten tons of hay contains about 250 pounds of atmospheric nitrogen. To manufacture an equivalent quantity of calcium cyanamid, which at this time is the most important commercial compound of atmospheric nitrogen, would require about three-eighths horsepower years of electric energy. This amount of electric current would be sufficient to maintain eleven 25-watt Mazda lamps in continuous operation. These, distributed throughout an acre of alfalfa, would be the visible energy equivalent of nitrogen values quietly and surely received by the alfalfa farmer through his crop. At commercial rates this nitrogen would be worth about forty dollars.

In itself considered, alfalfa stands first among Southwestern crops, being well suited to an irrigated and subtropical region; and having many industrial applications. It is a quick and reliable source of cash income from baled hay, honey and seed; it is the foundation of numerous feeding industries, alone or in advantageous combinations with carbohydrate feeds; it is relished by every form of livestock—poultry, ostriches, hogs, sheep, dairy cows, beef steers, mules and horses; and it is adapted for use in various forms—loose or baled hay, chopped feed or meal, as a soiling crop, as pasturage or even as silage. These characters have made alfalfa chief of our Southwestern crops, and as such it should be improved and specialized for various uses, its cultivation extended, its culture promoted, and careful watch kept against insect pests and diseases which may affect or threaten it.

But the greatest value of alfalfa lies, quite possibly, in its contribution to the soil of nitrogen and organic matter, which prepares the way for most other crops and which assures us of well nigh everlasting fertility for our agricultural soils. In this favored region, therefore, the misgivings of agricultural philosophers stand disproved; the defeats of agricultural commerce are forgotten; the costly ingenuities of humankind are discounted; and the quiet agencies of Nature, properly understood and utilized, assure us that our days will be long in the land which our patience has reclaimed.

R. H. FORBES.

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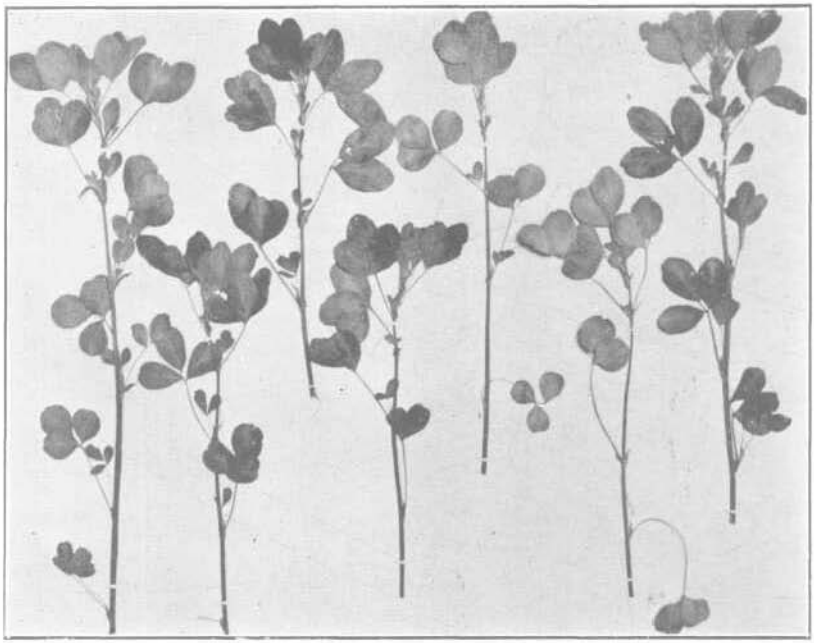

Fig. 1.—Mediterranean alfalfa.

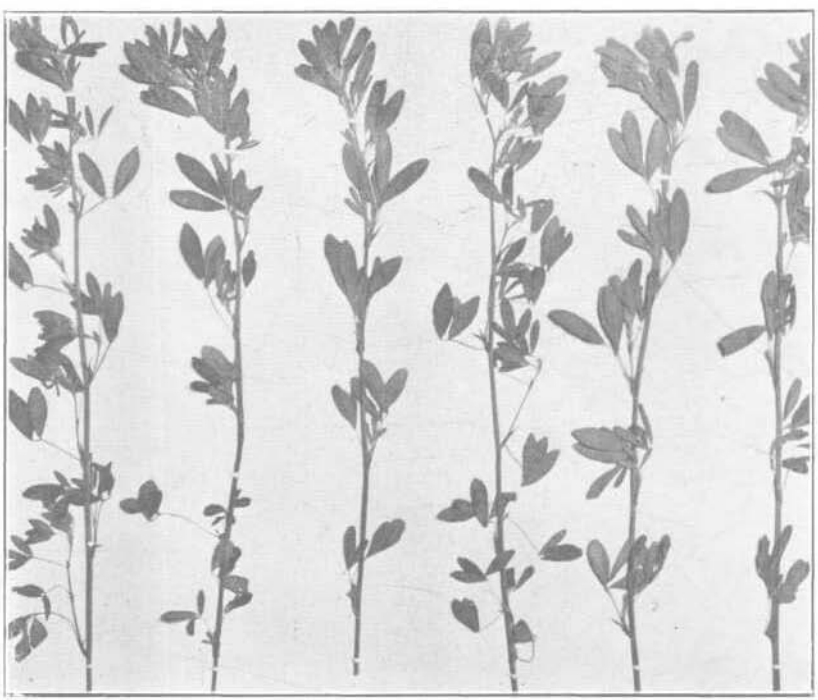

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PLATE II.—TYPES OF ALFALFA

Alfalfa in the Southwest

By Geo. F. Freeman

INTRODUCTION

Every agricultural community has its staple product What corn is to Illinois, wheat to Kansas and cotton to the Gulf states, alfalfa is to Arizona. More than one-third of all her cultivated land is devoted to its culture, and the revenues from it add more than two millions of dollars annually to the wealth of her farmers. More valuable than any other single crop, it forms the basis of the agricultural wealth of the State,—the safeguard of cattlemen in times of drought, the raw material for a growing dairy industry, the natural food for fine, fat stock, and the conserver of soil fertility by its deeply penetrating, nitrogen-gathering roots.

To serve the needs of the growers of this, Arizona's greatest crop, is the purpose of this bulletin. It is proposed, therefore, in the following pages, to bring together and coordinate those methods and practices which are now in operation on some of the more successful Arizona farms, in order that practical farmers throughout the State may profit by the experiences of others who have the same difficulties to overcome and the same conditions to satisfy as themselves. Furthermore, it is proposed to include the results of experiments and observations made at this Station, and the stations of neighboring states having similar soils and climate, together with the opinions of those who have made special scientific study of this crop.

Finally, it is hoped to furnish herein a source of information concerning the culture of alfalfa to those who may have recently or shall, in the near future, come into the State out of entirely different agricultural surroundings, and who are, therefore, wholly unfamiliar with the methods and practices necessary for success in this soil and climate.

Considering the general informational nature of this bulletin the writer has felt free to draw material from any source whatsoever that may throw light on the questions and problems which may confront the Arizona alfalfa grower. He has therefore taken advan-

tage, not only of his own personal experience for four years in Arizona, and several years in the alfalfa regions of the Central West, but also of such other information as has been received from time to time through correspondence and personal contact with successful alfalfa growers.

HISTORICAL SKETCH

As a commercial crop alfalfa has been grown in Arizona only about forty years. The supposition is that alfalfa was first introduced into southern Arizona and California by the pioneer Spanish settlers at a much earlier date, but it was not until after 1854, when it was received in San Francisco from Chile, that its commercial production became general and of economic importance in the irrigated sections. That this same importation was probably the source of the first alfalfa grown by Americans in Arizona, is strongly suggested by the fact that several of the earliest writers who mention this crop speak of it as Chilian clover. Neither McCormick (Resources of Arizona, 1865) nor Safford, Brinley and Campbell (Resources of Arizona, 1871) mention alfalfa.

The first white settlement of the Salt River Valley began with the opening of the Swilling ditch in 1868. The earliest definite reference to alfalfa in Arizona which is known to the writer, came ten years later and is that of Richard Hinton (Handbook of Arizona, 1878) who mentions it as growing near Florence. In the same paper he states that between eight and ten thousand acres of land were at that time under cultivation in the Salt River Valley, principally in wheat and barley, and that of the latter 6,000,000 pounds were produced. He also speaks of the Mormon colony at Tempe as growing, in addition to the cereals, peaches, grapes, tomatoes, melons, sweet potatoes, sugar cane, cotton and tobacco, but no mention is made of alfalfa. Again, alfalfa is not mentioned in Ms description of the crops grown on the large San Ysidro ranch near Yuma, though he does say that 500 tons of hay were produced, worth $40 a ton, In 1881, Patrick Hamilton in "Resources of Arizona" speaks of it in glowing terms. In the second edition of this work (1883) he states that there were 24,000 tons of this crop grown on 3000 acres in the Salt River Valley and that the Gila Valley produced 600 tons. IE the same year there were 30,000 acres under irrigation in Maricopa County. In 1910, when the area irrigated in the Salt River Valley was 129571 acres, alfalfa occupied more than half of the total.

In the same year the value of the alfalfa hay and seed produced in the Territory was, in round numbers, $2,500,000 or about 50 percent of the total value of all of the field crops including alfalfa, corn, wheat, oats, barley, hay and such other cultures as potatoes, broom corn, milo maize, etc. Within thirty years alfalfa is thus seen to have risen from comparative insignificance to the most important place in our agriculture. The reason for this quick rise of alfalfa to dominance lies in its almost perfect adaptation to our soil and climate, and to the abundance of rich forage which it produces. The experience of two thousand years has shown that it thrives best in the soils and climate of arid and semi-arid regions. No crop is so perfectly at home under irrigation and none so well adapted to withstand the extremes of heat and atmospheric aridity to which it is often subjected in this dry, sub-tropical country.

CULTURE OF ALFALFA

SOILS

ALFALFA IN ARIZONA SOILS

Alfalfa may be grown successfully on most types of soils found in Arizona. Along the rivers, it will flourish in the light Pecos sands;[1] it is at home in the Glendale loess or the dark loams of the Gila and the Santa Cruz. It produces good yields in gravelly loams, in stiff adobe and even in the heavy jointed clays of some of the upland districts. It is little affected by altitudes encountered within the farming sections of Arizona. It succeeds in the vicinity of Yuma not more than 50 to 100 feet above sea level, and in the valleys around Prescott at elevations of 6,000 feet.

SITUATIONS IN WHICH ALFALFA WILL NOT THRIVE

Where the soil is constantly saturated with moisture, or where the water table is less than two feet below the surface, alfalfa is not successful. Such soils in Arizona are usually too alkaline. Wherever the ground water is in continuous capillary connection with the surface, the great evaporating power of our dry atmosphere soon causes an excessive accumulation of soluble mineral salts. Concerning this matter Dr. Samuel Fortier says [2] "There is some difference of opinion as to what depth below the surface marks the danger line for alfalfa. It has been shown by Dr. Loughridge, of the University

1. See Ariz. Bul. No. 40
2. Samuel Fortier "Irrigation of Alfalfa" U. S. Dept. of Agriculture Farmers' Bulletin No. 373, p. 45.

of California, and by other soil physicists that water may be with drawn by capillarity from soil to depths varying from 4 to nearly 5 feet, depending on the character of the soil. This fact has an important bearing on the subject, because when the ground water is brought to the surface and evaporated, the salts held in solution are deposited at or near the surface. If these salts contain much sodium carbonate, sulphate, or even sodium chloride, all of which are grouped under the common term alkali, the crust formed by them will in time destroy the alfalfa. It may be stated, therefore, that when alkali is present in harmful quantities in the ground water it should not be allowed to rise nearer than four feet below the surface.

"In soils free from alkali but saturated with water, there is not the same necessity for holding the ground water continuously below a so-called danger line. In parts of Kern County, Cal., the ground water sinks to eight feet below the surface of alfalfa fields in summer, but rises to within 1.5 feet of the surface in winter. There is no indication of root rot and the plants have retained their full vigor. Numerous cases might be cited to show that the rise of water to within a (foot or two of the surface for comparatively short periods of time, does little injury to the plants On the other hand, wherever water stands continuously during the irrigation season within a few feet of the surface it is pretty certain to kill alfalfa in three years or less." Saturated soils, or soils from which there is poor under-drainage, are not well aerated. The tap roots, which have been known to extend 8 to 12 feet beneath the surface, must have a soil well supplied with air to a great depth in order that they may obtain oxygen for respiration. This respiration, or breathing, is necessary for the growth and health of the roots. Without air they are sickly, subject to disease, and unable to nourish well the tubercle-forming bacteria by means of which they store up atmospheric nitrogen, enriching thereby not only the hay crops produced but also the land on which these crops grow. It may be here mentioned that root rot and other soil diseases are much more prevalent on these water-soaked, heavy or poorly drained lands. Although alfalfa can perhaps do more than any other crop in penetrating and loosening up compact subsoils, it cannot do this where the subsoils are water-soaked. When it is not naturally present good drainage must, therefore, be provided for all ground where alfalfa is to be planted and if this cannot be done it is useless to sow the seed.

ALKALI

While not so resistant as sugar beets or barley, alfalfa may be grown in soil containing considerable alkali when once a stand has been secured. Thomas H. Kearney[1] says that on land containing not more than 0.6 percent total salts, alfalfa will make a fair growth. Buffum[2] states that "Alfalfa will grow in the presence of 1 percent white alkali provided the water level is not nearer the surface than two or three feet." Young alfalfa is much more sensitive than old. *' On land containing 0.2 to 0.4 percent of total soluble solids, and from .05 to 0.1 percent of black alkali, alfalfa, when well started, grows but it is often difficult to secure a good stand. Often a heavy irrigation just before seeding will result in a movement of the salts towards the subsoil and by the time they return to the surface the crop may have sufficient stand and vitality to endure the injurious effects of the salt."[3] After the field is once established, heavy growths of alfalfa will retard surface evaporation and prevent, largely, excessive re-accumulation of alkali. The different alkaline salts are not equally injurious. Alfalfa can endure seven to ten times as much of sodium sulphate, and four or five times as much of the chlorides as it can of the carbonate. The limit of tolerance depends not only on the total alkali present, but also upon the chemical nature of the salts which make it up. When there is but a trace of black alkali (carbonates) and the salts present are principally of the white form (sulphates and chlorides), alfalfa may be healthy where the concentration amounts to 0.5 percent of the total dry weight of the soil; but when sodium carbonate or bicarbonate makes up the whole or evea a considerable proportion of the soluble matter, as little as 0,1 percent may be decidedly injurious. Disregarding pot experiments and water cultures, the writer has collected and coordinated all of the available reports of tests of alfalfa on alkali land which have been published by the American Experiment Stations up to 1911. The following table gives in a condensed form the results of this collation. The figures represent the maximum quantities of the given salts when present alone or in conjunction with only very small quantities of the other two. The different columns are entirely independent, and the total does not represent the sum of the quantities given *in* the other columns, but shows the greatest amount of total soluble solids allowable in any case. These maxima could, therefore, only be approached when the salts present are made up of the less harmful sorts.

1. Thomas H Kearney ty» & Dept Agr Farmers Bulletin No. 446
2. - C Buffum. Wyoming Bulletin 39 (1898), p 47
3. U. & Dept. Agr. Bureau of Soils, Bul 35, p 24

LIMITS OF TOLERANCE OF ALFALFA FOR ALKALI SALTS

Salt	Mature alfalfa				Young alfalfa			
	Maximum quantity where healthy alfalfa was found		Limit of tolerance for growth		Maximum quantity where healthy alfalfa was found		Limit of tolerance for growth	
	Percent based on dry soil	Pounds per acre 4 ft deep	Percent based on dry soil	Pounds per acre 4 ft deep	Percent based on dry soil	Pounds per acre 4 ft deep	Percent based on dry soil	Pounds per acre 4 ft deep
Sulphates	.46 (2)	73600	(1X5) .70	112000	.10 (2)	10000	.21 (2)	33600
Carbonates	.08 (1)	12800	.10 (1)	16000	.05 (2)	8000	.01 (U)	8000
Chlorides	.27 (6)	13200	.50 (7)	80000	.27 (6)	43200	.50 (7)	80000
Total	.50 (2)(7)	80000	1.00 (3)(7)	160000	.27 (2)(6)	43200	.50 (7)	80000

NOTE—Lack of uniformity in methods of determining alkali salts in soils affect results within wide limits of error This table is therefore subject to revision after allowance for discrepancies between analytical methods has been made See Ariz Agr Exp Station 21th Ann Report, p 276

1 U S Dept Agr Bur Soils Bul 35, p 23, 24
2 Calif Agr Exp Sta Bul 133, p 27
3 Wyoming Agr Exp Sta Bul 39, p 47
4 Montana Agr Exp Sta Bul 54, p 102
5 Hilgard, Soils, p 467
6 Wyoming Agr Exp Sta Bul 43 p 75
7 U S Dept Agr Bureau Soils, Bul 34, p 10

ACID SOILS

The nitrogen gathering bacteria that live in the roots of alfalfa will not thrive in acid soils. For this reason such lands give unprofitable yields of alfalfa. Soils seldom derive their acidity from the decomposition of the rock from which they were originally formed. Sourness is usually brought about by over-drainage, by prolonged use of what are called physiologically sour[1] fertilizers such as muriate of potash or ammonium sulphate, or by the partial decomposition of vegetable matter in a water-soaked soil. The latter is the more frequent cause. The writer is not aware of any Arizona soils that are naturally acid. There is little danger of acidity from the other causes mentioned, for the reason that almost no commercial fertilizers are used within the State, and neither rain nor irrigation is usually so abundant as to over-leach the soil. Sourness due to the decomposition of vegetable matter in the presence of an excess of moisture Is extremely unlikely for the following two reasons: (1) Practically all Arizona soils are abundantly supplied with carbonate of lime sufficient in amount to counteract the acidity due

1. Wheeler, Hartwell and Tucker, Acidity of Upland Soils. Ann. Rept. R. I ..... Exp Sta. (1895), p. m

to decomposing vegetable matter for an indefinite period. (2) All of our irrigating waters, whether from wells or rivers, contain in solution enough lime to make up any deficiency there might be in the soil. Taking as an example the water of the Salt River and estimating a use of 4 5 feet a year, there would be added to the soil 1215 pounds of lime an acre annually. (See Ariz Bul. 44. p. 174). This is more than enough to counteract any amount of acidity that is liable to be produced by decaying organic matter during one season. Where the irrigating water is not sufficient to correct the acidity, or where the crops are grown upon the natural rainfall as in the Central and Eastern states, sour soils may be made fit for alfalfa by the application of caustic lime or ground limestone. Such applications are made every two to four years.

SUCK SPOTS

Alfalfa fields sometimes show spots where the stand dies out or makes a very poor growth. Where the normal growth is 15 to 20 inches high these spots frequently show a recovery of but three or four inches. They are usually found to be dry and hard even within a few days after a thorough irrigation. Farmers call these areas "slick spots" and usually attribute them to alkali. Such may be the case where the ground water is close to the surface. The accumulation of alkali in these situations has been discussed in a former paragraph. Thorough under-drainage followed by flooding will usually reclaim these areas without great difficulty.

There are slick spots, however, occurring on high land, which cannot so easily be ascribed to alkali. In these cases alkali, if present, must be considered as a result rather than a cause of the slick spot. The primary causes of these slick spots are two,—the first, a soil condition occurring naturally, and the second, a lack of preparation of the land on the part of the farmer. Although unseen above, areas of hard-pan frequently occur within a foot or two of the surface. These may be due to the accumulation of very fine silt and clay deposited from still water in a former depression, which has since been covered by the ordinary valley fill. These deposits of clay and silt become very firmly cemented together so that not only are they difficultly penetrated by water, but also they are resistant to the downward growth of even as vigorous a tap root as that of alfalfa. In this regard Scofield and Rodgers[1] have the following to say concerning lands within the Truckee-Carson Project in Nevada: "In some cases

1. Carl S. Scofield and S J. Rogers. The Truckee-Carson Experiment Farm, U. S. Dept. Agr. Bur Plant Industry. Bul. No 157, (1909) p 21

the soil on these clay flats contains alkali, but this is by no means always the case, m fact, the larger part of the trouble with these soils seems to be due to their mechanical rather than their chemical composition.

The relative impenetrability of soils of this hard land is well illustrated by an investigation made m an alfalfa field adjacent to the Experiment Station Farm. The field as a whole was fairly good, but it contained a number of spots irregular in size and shape, where the alfalfa plants were only from three to six inches high, while on the remainder of the field the plants grew to a height of thirty or more inches.

The boundaries of these areas of poor growth were found to be sharply defined. Thus, in a distance of 4 feet, plants would increase in height from 3 to 30 inches. An examination of the poor spots, as compared with the areas where the growth was good, showed that in the poor spots the alfalfa roots did not penetrate beyond 10 inches, while on the land where the alfalfa was good the roots penetrated to a depth of 3 feet or more. The roots on the small plants were apparently unable to penetrate the hard soil beyond the depth of ten inches. At this point many of the tap roots branched and spread out irregularly, instead of pushing on into the subsoil as they usually do.

A careful comparison of the good and poor spots in this field showed the soil of the poor spots to be very slightly finer in texture, containing a larger proportion of clay. It was apparent, however, that the chief difficulty on these poor spots was that the irrigation water had not penetrated beyond the depth to which the roots were found to have extended and only the upper 8 inches were found to be wet. Below this depth a layer of soil about 1 foot thick was very hard, the particles being cemented together. Below this hard layer the soil was more open, and at a depth of about 4 feet the underground water was reached.

An examination of the soil to determine the salt content in the good and poor spots brought out the fact that in the good soil the percentage of soluble material was very much lower than in the poor soil, and particularly was this difference marked at the lower limit of water penetration. The indications were that in the poor spots the irrigation water had failed to penetrate the soil to join the water table, and thus carry down the excess salt." Such soils can only be reclaimed by the breaking up or deep subsoiling of the hardpan layer. In some cases it has been found profitable to use dynamite. Again, some forms of tatxl£*ja can be and dissolved by very heavy and continued irrigation. (See Scofield and Rodgers, *loc. cit.*)

When improperly leveled, slight knolls are likely to be left amounting to probably not more than 2 or 3 inches. Although they may be lightly covered during irrigation so that they are unnoticed by the farmer, the water passes quickly over them and soon drains away leaving little to penetrate the soil. The ground is therefore not wet deeply. While a stand of young alfalfa may be secured on these areas, the roots do not penetrate deeper than the shallow surface moisture. The lower layers, therefore, remain dry, fail to be loosened up by the roots, and so become more compact. The small amount of water retained in irrigation is soon lost by evaporation through the almost perfect capillary system now formed by the compact soil, and this is further aided by the fact that the scanty growth of alfalfa allows almost full play of sun and wind on the naked surface. It is thus seen that when once started the slick spot intensifies itself, the dryness promoting compactness and lack of vegetable matter, which in turn augments dryness by perfecting the capillary system and exposing the soil to the full effect of the sun. The effect is nearly the same whether these dry spots have for their origin the improper leveling of the soil, or the poor preparation of the seedbed, whereby local areas may be left unplowed and hard. The harrow and the disk may pulverize the surface so that they are not noticed at seeding time, but the unbroken soil beneath often serves as the beginning of a hard or slick spot which intensifies itself in the manner above described. This is especially true where the irrigating water contains some alkali. The failure of the water to penetrate the deeper layers and unite with the ground moisture, thereby carrying downward the excess of salt, and its constant evaporation at the surface, has a tendency to cause an accumulation of soluble matter, often to a harmful extent. Indeed, black alkali deflocculates and makes plastic the soil and renders it still more impervious to irrigating water, without having greatly lessened its ability to lose moisture by evaporation. If taken before an excessive accumulation of alkali has occurred, these slick spots may be overcome easily by proper leveling, deep cultivation, and addition of organic matter in the form of liberal applications of stable manure well worked into the soil to the depth of at least one foot. The condition of certain areas in the alfalfa fields on the Experiment Station farm at Phoenix well illustrates the nature of slick spots, which were due originally to improper leveling. These spots, which were on Plots 4 and 35, were 3 inches and 1.5 inches above the surrounding field, respectively. The alfalfa on the first was 4 inches high while that surrounding it was about 25 inches high. On the

other slick spots the alfalfa averaged about 3 inches, and that surrounding it about 14 inches. During a certain irrigation the water stood 1 inch deep over the slick spot on Plot 4, and 2.5 inches deep over the slick spot on Plot 35. The depth of water over the normal area was 4 inches in both cases. Nine days later, June 11, the moisture content of the first 3 feet of soil, the hardness, and the water absorbing power of these soils, in place, were tested with the following results·

MECHANICAL AND MOISTURE CONDITIONS OF SOILS OF "SLICK SPOTS"

		Moisture content 1st three ft soil	Downward percolation of water in 6 inch cylinder	Iron pin driven in ten equal strokes
Plot 4	Slick spot	4 01	3 13 in per hr	13 25 in
	Normal	9 28	1 83 " " "	23 00 "
Plot 35	Slick spot	3 59	2 99 " " "	12 75 "
	Normal	11 16	2 75 " " "	26 85 "

The differences in moisture content of these areas are amply sufficient to account for the differences in the growth of the crop. The cause of the deficiency of the slick spots was not the inability of the surface soil to absorb moisture, but lay in the fact that their slight elevations caused them to get less water and that their greater compactness and exposure caused this moisture to be more quickly lost by evaporation. The remedy for these slick spots is therefore clearly set forth in the above paragraph,

PREPARATION OF LAND FOR IRRIGATION

The preparation of land to receive alfalfa cannot be considered too carefully It has already been shown how improper leveling may give rise to slick spots. The unequal distribution of water is not only wasteful but contributes to unevenness in stand, the drowning of the crop in one place, and its starvation from drought in another. Into the places where the alfalfa dies out weeds soon find their way to stock with seed and infest the whole field.

CLEARING

Before leveling, the ground must be rid of brush and such shrubby growth as may be present to interfere with the work. Heavy

mesquite, catsclaw, etc., will have to be grubbed out by hand or else torn up with a stump puller. Estimating the hand grubbing at 30 cents a tree, this cost may run as high as $100 an acre according to the thickness of the stand. The usual cost is from $5 to $45 an acre on ordinary mesquite land. It must be remembered that unless the wood has been removed previously, its value will partly compensate for the extra cost of clearing, and also that the presence of a thick stand of timber is a good indication of fertility. Brushy land can be cleared by dragging a heavy log or railroad iron across it, going once in each direction. After being broken off in this manner the loose trash can be raked up and burned. Only the heavy roots will have to be grubbed out, as the smaller ones will be torn up by the plow. Plowing should be to a depth of 10 to 12 inches, if possible. A heavy plow of the mould-board type should be used, and the team should be heavy,—three or four good animals. With such an outfit better work can be done and much expense in hand grubbing saved. Torn up stumps, roots and other trash should again be removed, when the land is ready to be graded. The field should be brought to a uniform slope away from the most elevated side, along which the supply ditch will be located.

METHODS OF IRRIGATION

The nature of the leveling work to be done will depend quite largely upon the method of irrigation to be followed. In the Yakima Valley in Washington alfalfa is irrigated largely by the furrow method since the soil is a very fine clay loam which puddles when wet and cracks open when dry. Running a small stream in the bottom of a furrow enab es the irrigator to wet the soil for some distance below and on each side lof the furrow and leave the surface comparatively dry. This system is not much used in Arizona and could be of possible advantage only on very stiff land, and where the head of water used is very small. Large areas of alfalfa in California are irrigated in checks. By this method certain pieces of ground are completely enclosed by levees 8 to 12 inches high. These enclosed areas are filled with water which is then allowed to soak into the soil. This method is suited to very stiff impenetrable soils upon which the water must be confined to make it soak in, and also to the use of large heads of water on nearly level land. It is little practiced in Arizona at the present time and the writer knows of but few situations in which it might be advantageous. Flooding from contour field lat-

erals is much used in Colorado, Utah, Montana and Wyoming. This method is adapted to very steep land, being used on grades as steep as 25 percent. In this method there is no attempt made to change the natural slope of the ground, only the small unevennesses being smoothed out. Ditches are run at intervals across the slope, usually 75 to 200 feet apart, and the ground below each ditch is watered by checking the flow with canvas or dirt dams and forcing it out over the banks of the ditch. In Arizona, where an abundance of more suitable land is available, little attempt is made to make use of such unfavorable situations for growing alfalfa. This method is, therefore, not further considered.[1]

Irrigation by the border method is in almost universal use among the alfalfa growers of Arizona and it is coming into more general use in California. This is due to the ease and economy with which medium or large heads of water can be handled, to the low initial cost of preparing the ground, and to the fact that it is suitable for use where the rotation of alfalfa with cultivated crops is practiced. By this method the land is watered in strips extending away from the supply ditch, usually in the direction of the greatest slope. The water is confined within the strip by means of "borders" or low ridges. These ridges may be formed with a buck scraper. After leveling, the scraper is run lightly at right angles to the slope. In each passage to and fro across the field, the scraper is dumped at each of the points where it is desired to build borders. This process is continued until enough soil has been collected to construct ridges of the desired height. After the rough formation of the ridges by the scraper they may be finished into shape with a shovel, or on a large scale with a harrow, wooden drag or V shaped ridger. In this latter tool, the apex of the V is left open and it is pulled with the largest opening forward. In addition to the side boards, boards on top will leave a ridge firmed and uniform on the top as well as the sides. The border ridges, when first made, are 10 to 12 inches high and 3 to 5 feet wide at the base. By the end of the first year, however, they have usually settled to 6 to 8 inches in height which is ample for most situations.

The border ridges may be formed quickly with a turning plow by throwing together four to six furrows. The open furrows left by the plow are then filled by means of a disk or drag-harrow. It is nearly impossible to do this satisfactorily, however, so that the borders next to the ridges are usually left slightly lower than the center. This

1 NOTE.—For a more complete discussion of the methods of irrigation in practice among alfalfa growers of TOOW sections, see Fortier, Samuel, Irrigation of Alfalfa, U. S. Dept of Agr. Farmer's Bul No. 373 (1909).

causes the water to run faster at the sides than at the centers of the borders and results in uneven irrigation or waste of water. For these reasons the scraper is much to be preferred to the plow in the formation of borders, since with the former the land is left perfectly level between the ridges.

LENGTH AND WIDTH OF LANDS

The desirable length and width of these border strips or lands depend entirely upon the nature of the soil, the slope, and the head of water to be used. The larger the head of water, the broader and longer may the lands be. This method of irrigation is not often used with heads of water less than 2 cubic feet *(80* miners inches) per second. In such cases the lands should be narrow (25 to 30 feet) and the length not greater than 400 to 600 feet. With larger heads, amounting to 5 to 10 cubic feet per second, the lands may be 50 to 60 feet wide and the length 1,000 to 1,500 feet. On steep ground or stiff soil into which the water percolates slowly, the length of the border may be greater than on the more open loams or sandy soils. Where the ground is very open or sandy much water will be wasted by percolation and lost in the underflow before it can be carried to the end of long lands. This difficulty is overcome by using a larger head to force the water over the field more rapidly, by confining it in narrower lands and by shortening the length of the lands,

SLOPE

The amount of slope is usually determined by the natural "lay" of the field. It cannot be changed materially without heavy expense in grading. On land which is too steep to allow the water to flow down the highest grade, the most economical method of correcting the defect will be to run the borders diagonally across the slope in a direction which will secure the proper fall. Each land is then leveled transversely. The field is thus terraced, each land forming a terrace. Where the strips are not made too wide this leveling can usually be done with a hillside plow, going over the land two or three times and turning the soil down hill at each furrow, after which it can be finished with an ordinary drag and harrow.

The slope usually preferred in the Salt River Valley is 20 to 45 inches per thousand feet. Some fields are irrigated where the slope amounts to 5 inches in 100 feet. Unless the land is very porous or the borders extremely long and narrow such a slope will allow but little penetration and hence the roots of the alfalfa will be short,

the yields poor, and the stand liable to be injured by hot weather. Sandy and porous loam soils into which the water percolates readily may have almost any amount of slope below that which would cause washing. Many irrigators prefer that the land should be perfectly level or with only sufficient slope to allow slow drainage and prevent collection of the water into standing pools. On porous land with good under-drainage no harm can come from flooding perfectly level borders. In such cases, however, a larger head of water and higher borders are needed in order to force the water over the entire tract as promptly as possible, preventing a waste by percolation

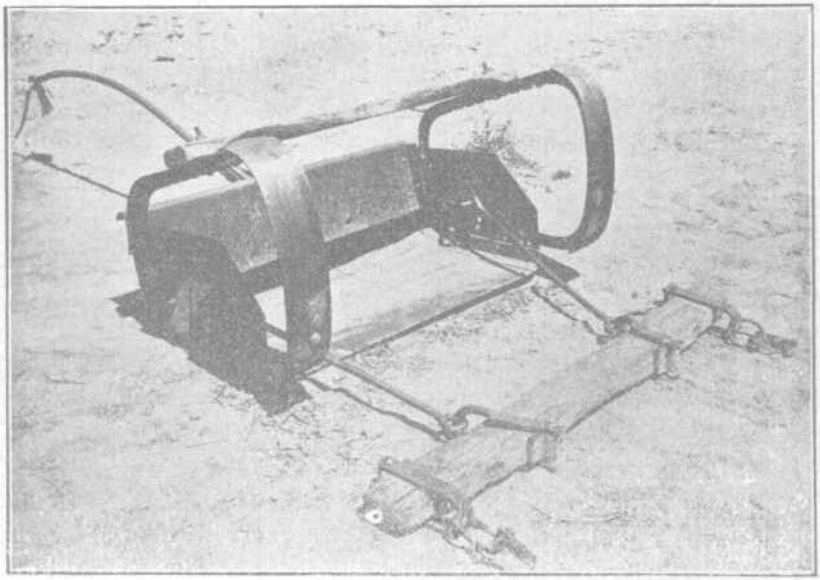


Fig. 1.—Fresno scraper.

near the head of the border and a loss in yield by insufficient irrigation at the other end. On stiff soils that are level, there is less danger of waste of water, or difficulty in forcing the water throughout the length of the border. In fact, here the lack of slope has the advantage in causing the water to stand longer on the ground, thereby wetting to a greater depth than would otherwise be possible. The only danger in such situations is that where too much water is applied, it may not be able to get away, thereby collecting in the lower places and forming ponds which ultimately may drown the alfalfa, and promote the infestation of the field by a growth of water grass, dock and other weeds. In such cases artificial drainage should be provided.

LEVELING IMPLEMENTS

Where the land is very uneven the grading will have to be done before the borders are laid off. When necessary to carry the dirt for a considerable distance some form of wheel scraper is essential. The one most commonly used in Arizona is the Fresno scraper, such as is in common use on railroad and other heavy grading work. Where the distance is short the buck scraper is in common use. It is more simple in construction and is cheaper. With the aid of a local blacksmith this tool may be made at home. Small irregularities due to stump holes, wind ridges, unevenness in plowing, etc., can be smoothed out by means of a homemade drag or raft.

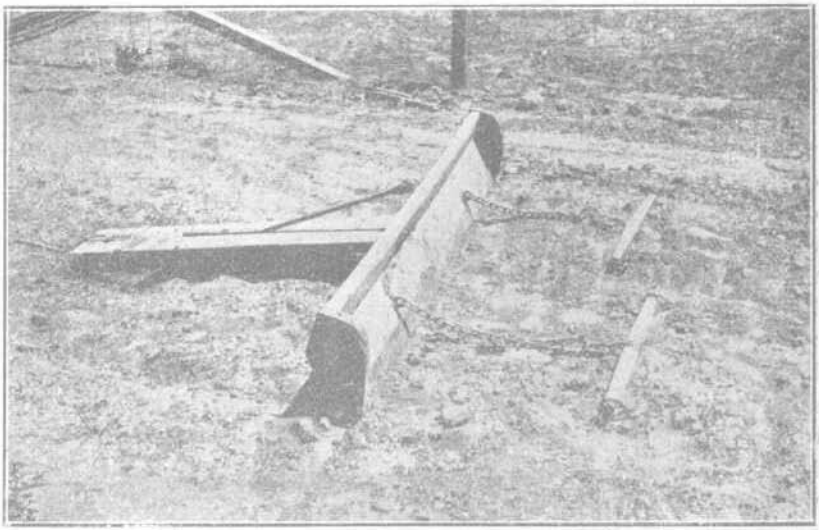


Fig. 2.—Buck scraper.

COST OF LEVELING

After the stumps and brush are removed from the land the cost of plowing, leveling and throwing up the borders will depend entirely upon the amount of grading to be done. Where no other finishing is required than may be accomplished by the raft, this ought not to cost more than $4 to $5 an acre. Where much soil is to be moved and it is necessary to use the Fresno or buck scraper, the cost will be proportionately higher. Ordinarily the cost will be from $5 to $15 an acre, but where there are many hummocks, small ridges,

or trees surrounded by wind driven sands, the expense of preparation for irrigation may be as much as $40 or $50 an acre or even more.

SETTLING

On soil which is ordinarily very loose or where much grading has been done, it is not best to plant alfalfa the first year after preparation This is due to the fact that oftentimes the soil will settle to such an extent that the crop cannot be evenly watered. The writer observed a field in the Gila Valley where alfalfa had been planted on new ground that was very porous. The leveling had been carefully attended to before planting and a perfect stand secured throughout the field. After a few heavy irrigations, however, several spots in the field began to settle. One area of about three acres settled nearly six inches and caused a pond to be formed every time the field was irrigated. The alfalfa in the lower parts of this area soon died out and its place was taken by water grass. The writer has also observed several instances where similar settling has occurred in the loose dirt where a foot or more of fill has been made. In such situations it is best to grow some temporary crop as corn, barley or beans the first season. When the ground has been thoroughly wet to a depth of 8 or 10 feet no further settling is likely, and it may be re-leveled, bordered, and planted to alfalfa with a better assurance of permanence. Firmer, well settled soils are not open to this difficulty and may be planted to alfalfa at once after clearing and leveling. The writer has seen many excellent fields of alfalfa that were planted in raw land.

PREPARATION OF SEEDBED AND PLANTING

Where alfalfa is sown on land that is already under cultivation, It is convenient to have it follow some crop that comes off in early summer, such as potatoes, sugar beets, spring sown beans or tcparies, or a winter grain such as wheat or barley.

As soon as the preceding crop is off, the land should be given a shallow plowing or disking and a thorough irrigation. This will promote the germination of the weed seeds present. Before the seeds from the crop of weeds are ripe, the ground should be given a thorough plowing, 8 to 12 inches deep if possible. If the border ridges were destroyed in plowing, they should now be reconstructed. The space between the borders should be thoroughly pulverized with the disk and drag-harrow and a fine, smooth and level (across the lands)

seedbed prepared. In this condition it may remain dry until just before planting. When the planting season arrives the ground should first be thoroughly irrigated. As soon thereafter as it will do to go on the ground the seed should be put in.

SEEDING

A more even and perfect stand can be secured by the use of a press drill. The seed should be covered 1 to 1.5 inches deep and the machine set to sow 10 to 15 pounds an acre. Where a press drill is not available any form of hand seeder may be used or the seed may even be broadcasted by hand. By hand, the seed is sown

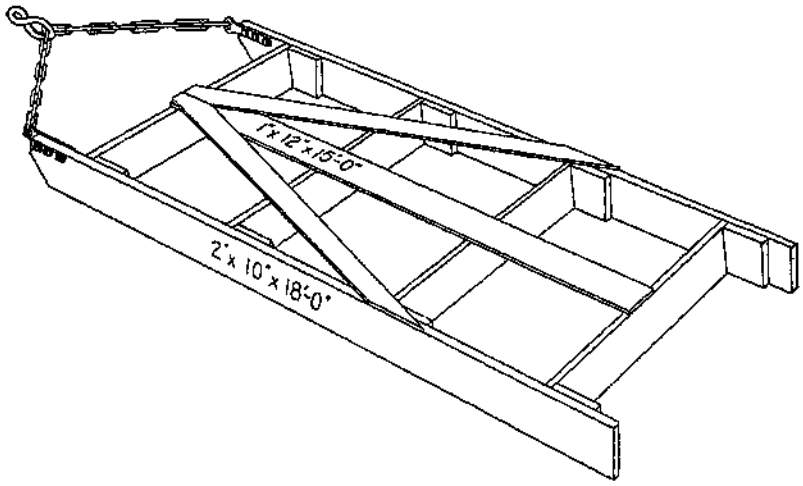


Fig 3.—Raft or drag leveler (Drawn by A. L. Enger)

on the surface of the ground and covered by means of a drag, disk, or spring-tooth harrow. It will generally be necessary to run the harrow over the field and then cross harrow in order to cover the seed sufficiently. Many farmers have successfully covered their surface sown alfalfa seed by dragging brush over the fields, going over it from one to three times; but at best this is a crude method and should be replaced by a better one wherever possible.

Sown in the above manner on soil which has been deeply and thoroughly saturated, the seed should come up without further attention, If possible it is far better to have the plants come up with this preparation than to give a second irrigation before they have reached the surface, since there will be left a loose mulch through which the delicate seedlings push their way without difficulty. The

surface mulch, moreover, prevents the rapid drying of the lower soil layers, and the tap roots of the young plants are able to push downward, keeping pace with the receding moist layers. The plants are thus induced to send their roots down from the very beginning, establishing themselves more permanently than will plants that have been furnished with a continuous supply of surface moisture. In this way the plants may become two or three inches high before a second watering. They are then much less liable to be covered by silt, or to washing of the surface during irrigation, than are plants that must be irrigated soon after they come up.

It sometimes occurs, however, that a second irrigation will be necessary to bring up the seed. In such a case care and subsequent attention will be necessary to secure and maintain a stand. After the soil is once wet and the surface mulch destroyed, it must be kept constantly damp until the plants are out of the ground, since if a crust is allowed to form the seedlings will be unable to break through. Moreover, even after the stand is up, the compact and now unshaded upper surface will promote evaporation. Frequent irrigations will therefore be necessary until the alfalfa is large enough to begin to shade the surface and in these irrigations, especially when the plants are very small, much of the stand is covered with silt or mud and destroyed Moreover, as already stated, such frequent irrigation tends to the development of a shallow root system, a defect from which the alfalfa may not recover in the course of several years.

COST OF PREPARING THE SEEDBED AND PLANTING

It is easier and cheaper to kill weeds before planting than afterwards, or than to have them levy an annual tax upon the income through decreasing yields. Perennial weeds should be destroyed by withholding water from the soil and by following with repeated plowing and harrowing during the dry season until all of the roots of the objectionable plants have been killed. Where the soil is full of the seeds of troublesome annuals, it should be plowed, irrigated and disked or harrowed until all of these noxious seeds have been induced to sprout and are destroyed.

The cost of preparing the seedbed and sowing the seed is variable and depends upon the season, the nature of the soil and the preceding crops. Where the land is rough, foul with weeds, and needs much leveling, or the soil is stiff and difficult to form into a good seedbed, the cost will manifestly be relatively high, The following stateraat are offered as approximate estimates of the cost of preparing

and seeding an acre of alfalfa on old ground. The two columns are intended to cover the ordinary range in this cost as influenced by the factors of soil, season, amount of leveling required, weeds, price of labor, etc., that might be expected under average Arizona conditions. The items of expense are given in the order in which they most likely occur.

Double disking after removal of preceding crop		$ 1.00
Irrigation.		.25
Irrigation	$ 25	.25
Plowing..	2 00	2.00
Harrowing and bordering	50	1.00
Disking and leveling	1 00	5 00
Irrigation	25	25
Ten to twenty pounds alfalfa seed @ 15c	1 50	3.00
Drilling .	25	.75
	$ 5 75	$13.50

In the case of land infested with Johnson or bermuda grass, where it becomes necessary to fallow without irrigation throughout the preceding winter or spring, the cost will, of course, be correspondingly increased. For this purpose each additional plowing may be estimated at $2 an acre, disking at 50 cents and harrowing at 25 cents an acre.

TIME TO SOW

Alfalfa can be sown in Arizona with a good chance of success during any month from September to May. If planted during the warmer months the ground loses moisture so fast that it will dry out deeper than one dares to plant the seed before it has time to germinate. When, however, the seed is again irrigated before coming up, the ground bakes around the seedlings so tightly that they are unable to force their way to the surface. Stands may be secured in the hottest weather, but in order to do so the seed must be planted shallow and then watered every two or three days until the plants are up. Such a proceeding would be impracticable in large fields. Alfalfa is therefore best planted during the cooler weather of fall, winter or spring, when evaporation is not so great. The conditions are then usually such that the seed may be planted on a moist and well prepared seedbed that will retain its moisture long enough to bring up the plants without further irrigation. When, however, a second irrigation is necessary, the ground does not bake so

quickly and the seedlings will, for the most part, get through the surface before a crust is formed. Good stands of alfalfa that were seeded in winter (late November to February 1) are common, but seeding during this season is risky on account of frost injury. If a hard freeze occurs soon after the alfalfa gets through the surface, when it yet has but two leaves, and especially when the soil is damp from recent irrigation or winter rains, a large proportion of the young plants may be killed. The writer knows of an instance where a beautiful stand of forty acres was destroyed in this way. After the young plants have three or more leaves, no degree of cold occurring in Arizona is likely to injure them.

Good stands can be secured during February and March. Spring planting, however, is open to the disadvantage that the young plants go into the hottest and dryest part of the summer (May and June) with poorly developed root systems. The taproots have not yet penetrated deeply and if a shortage of water should occur (which is more liable at this season than any other). the plants suffer from drought and the stand is apt to be seriously depleted. Moreover, spring planted alfalfa gives but light yields the first season and requires more frequent irrigation and greater attention than that which is planted earlier.

The best time to plant alfalfa is from September to November inclusive, according to season and locality. Planted at this time the young seedlings, favored by the mild temperatures of our autumn climate, get sufficient start not to be injured by the sharp frosts of December and January. The labor and expense of frequent irrigations are made unnecessary by low evaporation during the cool weather, and this is further reduced by the moisture obtained from whatever winter rains that may occur. While the tops grow but little during the cold season, the root systems are developing steadily. The alfalfa, therefore, goes into the hot, dry period of early summer with wide spreading and deeply penetrating roots. This enables it to withstand heat and drought and return profitable yields even during the first year of its occupation of the soil.

SEED

Alfalfa seed should have a bright greenish-yellow color. Brown or shriveled seeds are either decayed or immature and will give a low percent of germination. The presence of trash or other inert matter reduces the number of seeds per pound and lowers the stand when a given weight per acre is sown. Weed seeds of all kinds should be guarded against. (See Weeds, page 307.)

If the seeds appear fresh and bright greenish-yellow, a germination test will seldom be necessary. Such a test, however, is easy to make and gives a true estimate of the value of the seed and the quantity that should be sown per acre. A convenient method of making this test is as follows Place 100 alfalfa seeds between two clean, damp pieces of blotting paper or several folds of clean white cloth. Lay this on an ordinary dinner plate and invert another over it to prevent rapid drying out. Place the dish in some fairly warm place in the living room and keep the cloth or blotting papers moist but not saturated for three or four days. At the end of this time good seed should show 75 to 80 percent of sprouts. At the end of ten days 85 to 95 percent should have germinated, but for practical testing, when kept in a moderately warm room, four or five days is sufficient to determine the value of the seed.

Do not buy alfalfa seed because it is cheap. Poor seed is expensive at any price. It never pays to plant trash or weed seed. Planting a greater quantity to the acre in order to compensate for inferior quality more often results in increasing the stand of weeds than that of the alfalfa.

Age. Alfalfa seed is usually thought to deteriorate very rapidly in quality after it is two years old. This is probably true of commercial seed as ordinarily stored. When, however, it is kept perfectly dry and without violent changes of temperature, it loses very little of its vitality before the end of 6 years. Headden[1] found an average germination of 94.25 percent in seed that was 12 years old, and 63 percent in sixteen-year-old seed. From a number of experiments extending over more than ten years he says: "I think it safe to conclude that the limit of vitality of good mature alfalfa seed exceeds 16 years." Ewart[2] reports a germination of 20 percent in alfalfa seed known to be 50 years old. In order to retain their vitality for such long periods these seeds must have been kept in the very best of storage. Where alfalfa seed has been stored in sacks or bins in an ordinary warehouse the writer would not recommend for planting any that is known to be more than two years old and unless properly tested would urge its rejection after three years of such storage.

Amount to sow: Plump, well matured alfalfa seed should number about 200,000 to the pound. Where 15 pounds are sown to the acre we would obtain 3,000,000 plants if all germinated. Estimating that under field conditions only two-thirds of the seeds produce

1. Headden, W. P., Alfalfa Colo Agr. Exp Sta. Bul No. 110 (1906) p. 15.
2. Ewart. Alfred J' On the Longevity of Seeds Proc Roy. Soc. Victoria, Vol. XXI (New Series) Pt 1, (1908) p 110.

plants, we would have 2,000,000 seedlings or about 45 plants to the square foot. This number would be considered a good stand. As the plants grow older they crowd each other and some die With an original stand of 45 plants to the square foot, more than half usually succumb during the first year. At two years 11 plants to the square foot is an abundant stand and this will be normally reduced to an average stand of 5 to 6 plants by the end of 4 or 5 years Alfalfa 6 or 7 years old having an even stand of 3 to 4 plants to the square foot is ample Stands of alfalfa 10 years old having an average of 12 plants to the square foot have been recorded[1]. Such crowding, however, is not usually to be advised, since the root systems are not so well developed as in the thinner stands. The quality of hay is no better and when it is desired to take a seed crop such a thick stand is harmful. The same author reports fair 3 yields from as little as an average of 1.5 plants per square foot, As the plants decrease in number their size increases and they send out more stems above and roots below the surface and thus the ground is continually occupied, neither the yield nor the quality being diminished. When, however, so many plants die out that they do not touch each other and completely cover the ground at maturity, both the yield and quality will suffer,—the former on account of the failure of the plants to appropriate the whole area and the latter by reason of the increase in size and woodiness of the stems of these isolated plants.

If every seed germinated, 12.5 pounds of seed to the acre would be ample. Since, however, this is never the case, more is usually sown. The quantity depends largely upon the preparation of the seedbed, the moisture supply, and the danger from weed infestation. The more perfect the seedbed, the higher will be the percentage of germination and the less seed required to secure a stand* In dry-farming, the stand must necessarily be thinner on the ground (2 or 3 plants to the square foot) in order that each plant may secure an ample supply of water. For this reason many growers of alfalfa in semi-arid sections find it best to sow not more than 8 to 10 pounds of seed to the acre. On the other hand, in humid sections, where the danger of weeds is great, 20 pounds to the acre is not too much* A dense stand is thus secured whereby the alfalfa covers and takes possession of the ground when quite young, leaving less opportunity for the ingress of weeds,

Under average conditions found in the irrigated sections of Arizona, with the soil well prepared and a good quality of seed, about 15 pounds should be sown to the acre. This ought to give an average

1. Headden, W. P., Alfalfa [illegible] p. 40.

of 45 plants a square foot when young, which will normally be reduced by natural thinning to 4 or 5 plants a square foot by the time the alfalfa is 5 or 6 years old. When it is intended for the field to be devoted largely to the production of seed, not more than 10 to 12 pounds should be sown,

INOCULATION

Like other plants of the pea and bean family, alfalfa is able to obtain nitrogen from the air. It accomplishes this through bacteria which penetrate the roots of the plants and there grow in symbiotic relationship with their hosts. The presence of these bacteria is shown by small, irregularly shaped, frequently branched nodules upon the smaller rootlets. Alfalfa seems to have become so dependent upon the presence of these organisms that except on highly fertilized land it is not healthy without their presence. These bacteria live and are abundantly present everywhere in the soils of regions in which alfalfa or one of its near relatives is growing. The fact that these bacteria will not grow in acid soils is the most probable cause of the almost certain failure of alfalfa in such soils. In sections where alfalfa has never been previously grown the proper bacteria may be entirely absent. In such a case they must be introduced and planted m the soil before alfalfa can be grown successfully. This may be accomplished eitner by spreading soil from an old successful alfalfa field upon the land which it is proposed to seed, or by sowing along with the alfalfa, pure cultures of the bacteria in question. By the latter method, the bacteria are grown in specially prepared media and sold in tubes or bottles, These are to be dissolved, diluted and sprinkled on the seed before planting, or else the seeds are dipped into the diluted liquid cultures containing the special bacteria, after which they are dried in the shade and sown immediately. These cultures have not been uniformly successful. Practical growers, as well as those who have studied the matter from a scientific standpoint, are now quite well agreed that the method of soil transfer is much more sure and satisfactory. Three or four hundred pounds per acre of soil from an old and thriving alfalfa field is scattered over the well prepared seedbed and immediately harrowed or disked in. This point should be attended to in order that the direct rays of sunlight, which are so deadly to bacterial life, may not kill the bacteria while they are exposed on the surface.

Artificial inoculation, however, seems to be unnecessary in Arizona to account of the almost universal presence of the alfalfa tuber

cle-forming bacteria within its soils. Irrigation water, the droppings of stock grazed or fed on alfalfa, and the use of alfalfa hay by teamsters and travelers, have distributed these bacteria throughout the State. In all \alley lands where alfalfa has been planted, natural inoculation is prompt and efficient. Even on the higher mesas and in mountain parks, artificial inoculation does not seem to be necessary. Director R. H. Forbes records that near Lakeside, Arizona, at an elevation of 6,000 feet, on land which had never grown this crop previously, a flourishing field of young alfalfa was observed several miles distant from any other alfalfa. On examination, the roots of these plants revealed an abundance of well developed tubercles. In view of these facts, any mention of artificial inoculation in this publication would be superfluous were it not for the inquiries from those of our farmers who have received advertisements of inoculating material, or who have read of the benefits to be derived from it in other sections.

NURSE CROPS

Formerly, alfalfa was frequently sown with a nurse crop. At the present time tnis practice has been almost entirely abandoned except in special cases. The nurse crops most frequently used were wheat, oats, rye and barley. Experiments carried out by V, A. Clark[1] demonstrated the injurious effects of the fall planting of winter grain with alfalfa. The following March, the alfalfa in pure cultures was 15 to 17 inches high while that with the nurse crops varied from 12 inches down, averaging not more than six to eight inches high. The weights of the plants in pure cultures averaged from 21 to 75 grams in different parts of the field, while the averages from the several plots grown with a nurse crop varied from 2 to 10 grams. Differences in root development were nearly as marked. Alfalfa roots *in* the pure cultures had reached a depth of 18 inches while those grown with nurse crops had penetrated to the depth of one foot only in the most favorable situations. "Lack of food supply or water could not account for this difference between plants grown with or without nurse crops, for the land is naturally rich and was kept well irrigated. Alfalfa plants grown with nurse crops have every appearance of suffering from insufficient light. The development of leal expanse is greatly reduced, and the internodes are abnormally lengthened, but decreased in number, the plant substance is soft and watery, showing insufficient elaboration of food material." to the shallow

1. V. A Clark. Observations on Nurse Crops for Alfalfa. Ariz. Exp. Sta. Timely Hints for Farmers, No *86* (1907).

root systems and tender growth of the shaded stems, even after the removal of the nurse crop, the weakened and undeveloped alfalfa plants are poorly fitted to withstand drought or contend with weeds. Whatever is gained in the extra yield of the nurse crop itself is lost in the poor stand of alfalfa secured. The growing of a nurse crop is frequently advised on sandy land, which is liable to blow during winter. Here oats are sown with the alfalfa in the early fall. The tufts of oats which are quickly formed protect the soil from drifting, and being killed by the frost in early winter, they still serve as a protection to the young plants, or to hold the snow in regions where this occurs. With the coming of the next growing season the alfalfa has developed a sufficient crown and root system to itself protect the soil. Such use of a nurse crop in Arizona would seldom be necessary, however, for the reason that except in high altitudes we are rarely troubled with drifting of the soil by the wind, and whenever it occurs it could be promptly stopped by a light irrigation. A nurse crop is also sometimes used where alfalfa is to be planted in spring, especially on very stiff land which bakes readily. In such cases the grain should be cut for hay before it matures in order to prevent undue shading and consequent weakening of the alfalfa. It must be remembered that a nurse crop has the same effect upon the alfalfa as an equal crop of weeds. Its only advantage over weeds is that it is more easily controlled and destroyed when the proper time comes,

VARIETIES

The natural variability of alfalfa and the wide range of soil and climatic factors within which it has been grown, have produced many distinct types and races. Whenever alfalfa is grown for a long series of years in a given region from seed produced locally, it slowly becomes acclimatized. Those mixtures or variations which are best suited to the conditions prevailing, flourish and crowd out the less favored individuals. Strains acclimatized to a given region are called regional varieties. In transferring seed from one country to another the measure of its success is usually proportional to the degree of similarity between the climatic factors of its old and new homes. However, unless we have definite information as to the exact origin of an imported strain, the length of time that it had been planted in that given region, and the local conditions under which it was grown, we must be very uncertain as to the likelihood of its value in Arizona, Not all strains of alfalfa from Turkestan, for example, have an equal

value or climatic adaptation. Local conditions and the number of years they had been grown in that region will largely govern their quality. These facts are strongly emphasized by a series of tests covering a period of seven years with 44 one-twentieth acre plots at the Station Farm near Phoenix, and 18 plots at Yuma. These plots included 26 distinct strains from practically every alfalfa growing region in the World. There were 7 strains from Mexico and South America, 5 from different parts of the United States, 10 different strains from Turkestan and other parts of Asia, and 4 strains from Arabia, Algeria and Tunis, with 1 plot of unknown origin. The wide variation in the character of the plots from the same general region is most striking. Even the type varies strongly. Among the Asiatic strains one type occurs which strongly resembles the typical Peruvian alfalfa, the plots from Europe show a strain of Sand Lucerne aside from the ordinary alfalfa that might be expected from that region; and among the South American alfalfas there are two distinct types. Even within the same plot many different strains and types occur. Among the stout, stemmy, narrow leaved and strongly hairy plants on the plots of the Peruvian type, individuals may be found running all the way from the ordinary small leaved, smooth American alfalfa, to the large, succulent, broad leaved alfalfas of the Mediterranean region. High and low yielding strains have come from every region from which seeds have been drawn. No general deductions as to the uniform superiority of any certain regional variety can therefore be made. While all the strains so far introduced are mixtures, the high-yielding power of certain importations is undoubtedly due to the predominating presence in them of one or more races of superior quality. It is important, therefore, that some constituted authority, having the means, as reliable seed growers or the experiment stations, make these tests of imported strains, find and isolate the excellent pure races, and purify them by selection to type before they are distributed for general planting. For these reasons the writer would advise that only locally tested seed be used for field planting in Arizona, and that where importations are made the quantity should be small and merely for the purpose of testing. If the new variety proves valuable it is best to grow increased plots of it and raise the seed at home for larger plantings.

As an example of an imported strain which has proven valuable, Peruvian alfalfa may be mentioned. The seed of this strain is now being produced *in* large quantities by the Yuma Alfalfa Seed Growers' Association. It is an upright, vigorous and very productive sort with narrow leaves and light purple flowers, Peruvian alfalfa

is inclined to be a little stemmy and the plants are somewhat hairy, but these difficulties are largely overcome when it is grown in a thick stand.

Aside from the Peruvian, out of the 26 imported strains tested at this Station only 4 seem worthy of further trial. These include two from Europe and one each from South America and Turkestan. The strains from Arabia and the Mediterranean region were very promising for the first year or two of their growth in the experimental plots at Phoenix, but they soon lost stand to such an extent that their yields dropped below the margin of profit. This same difficulty has been experienced in other parts of Arizona where these strains have been tested. The Mediterranean alfalfas are vigorous, among the first to start in the spring, and the last in autumn to cease growth. For these reasons they will generally yield one more cutting to the season than any other variety, with the exception of the Peruvian. Were it not, therefore, for their tendency to lose stand, or if hardy strains of them could be developed, they would make a valuable introduction.

Finally, with regard to varieties, it may be stated that, with the exception of the Peruvian alfalfa already mentioned, and in the absence of selected, tested and purified strains of other sorts, our home-grown seed is probably better than any regional strain which we would be able to import indiscriminately at the present time. The fact that Arizona now is, and should continue to be, an exporter of high grade alfalfa seed rather than an importer, perhaps more than anything else emphasizes the necessity of carefully guarding the purity of our local type and standard of excellence,

CARE AND CULTURE OF YOUNG ALFALFA

After a stand of fall-seeded alfalfa is secured, very little attention will be needed until the following spring except to see that it does not become too dry. Where no rains occur, one irrigation of 2 to 3 inches of water a month should be ample throughout the winter until after the first cutting, sometime during the following April 01? early May. When winter rains occur these may take the place of one or more irrigations. It is best not to keep the surface soil saturated during this first winter because, as already stated, young alfalfa developes a stronger and deeper root system in fairly dry ground. After the first of May, it should be irrigated twice for each cutting, the treatment in this regard being the same as for old alfalfa.

In late winter or spring seeded alfalfa, irrigations immediately following and during the first summer must be more frequent than

would be necessary for fall sown plants which go into the hot weather with better developed root systems. Here water should be applied at least twice a month until the beginning of the summer rams.

With fallsown seed the first cutting, usually coming in April, may give a light crop of hay,—as much as one-half ton to the acre The subsequent crop should, of course, yield more. The yields from spring sown alfalfa will be light throughout the first season. If weeds appear and threaten to choke the young alfalfa, it may be necessary to clip the field one or more times in order to keep them down. The mower bar should be set 2 to 3 inches high. If young alfalfa be clipped too closely before a definite enlarged crown has been formed, many plants may be killed.

Even where weeds have not become troublesome it is the practice of many successful alfalfa growers to clip the young alfalfa. They maintain that by this means a better crown and root system is secured. As a general rule of procedure it may be said that alfalfa should be cut when any of the following conditions appear: (1) When weeds begin to choke or smother the young plants, (2) when one-fifth to one-third of the plants begin to bloom, (3) when new shoots begin to appear at the base or crown, (4) when the plants stop growth and begin to turn yellow and, (5) when growth is checked by stem or leaf diseases. When, after clipping, the herbage remaining does not shade the new growth nor is worth saving for hay, it may be left on the ground except where the crop was cut on account of the prevalence of leaf spot or other leaf or stem diseases. In such cases the hay should be carefully raked and removed in order to get rid of as many as possible of the spores of the fungus. When this is done, the new growth is frequently free from the disease or sufficiently vigorous to throw it off and bring to maturity a healthy crop.

Alfalfa less than one year old should not be cultivated with a disk, spike-disk, or spring-tooth harrow. The root systems have not yet taken sufficient hold on the ground to prevent many of the plants from being pulled out and destroyed by the vigorous cultivation which these tools give. Moreover, if the land has been well prepared before seeding, such cultivation should not be necessary. Fall sown alfalfa may often be cultivated with an iron tooth drag harrow the following spring with advantage in order to break up a crust and provide a light surface mulch. When this is done the teeth of the harrow should be set with sufficient slant that they do not collect trash and cover the young alfalfa badly.

It is not good practice to pasture alfalfa until it is one to one and one-half years old. The writer knows of several instances when fall

sown alfalfa was lightly pastured the following spring without seriously injuring the stand. This, however, is a dangerous practice and more frequently results in a greater loss in future crops than the pasturage secured is worth. Before the enlarged crowns are formed, young alfalfa is especially liable to injury from trampling, since the stems are weak and easily broken or cut off by the sharp hoofs of the cattle below the level where the buds are readily formed. Close grazing at this stage also has the same effect as close clipping, in the reduction of the stand by killing many plants.

CARE AND CULTURE OF OLD ALFALFA

IRRIGATION

In parts of California having considerable winter rainfall, and in Colorado, Wyoming and the Pacific Northwest, alfalfa will produce very nearly its maximum yields with the application of only 2 5 to 3.5 acre feet of water a year in three or four irrigations. In Arizona, where there is less winter rainfall, a higher temperature, and twice the average summer evaporation, being a little over 2 inches a week,[1] a much greater quantity can be applied with profit. It is not necessary to irrigate alfalfa during the winter. This, however, is usually a season of abundant water. The rate of evaporation during the cooler months is also low. For these reasons it is a good plan to give one or two heavy irrigations during the winter in order to thoroughly saturate the subsoil. When this is done the crop starts earlier in the spring, and is not so liable to suffer from drought during the extremely hot weather of June and early July. After harvesting starts in the spring there should be 2 irrigations for each cutting. The first should come near the mid-development of the crop and the second about 3 days before harvesting. By this method both applications of water are made upon ground well shaded by the half grown or mature plants. There is, therefore, little loss from evaporation and the moisture penetrates more deeply into the subsoil. Another advantage in making the second irrigation just before rather than just after cutting, is that the abundance of moisture in the soil stimulates the plants to an immediate resumption of growth. Where the naked stubble is required to wait in dry soil for the curing and removal of the hay crop before it can be watered, renewed growth Is delayed for several days. When water is finally applied it does not penetrate so thoroughly. The saturated

1 Livingston, B E 4 Study of Evaporation and Plant Distribution. Plant World Vol 14. No 0, (1911) p 210.

and exposed surface dries out rapidly and bakes into a crust, forming the best possible conditions for the rapid loss of water from the surface, and the consequent suffering of the crop from drought. This condition also promotes the rise and accumulation of alkali where this is present to an appreciable extent in irrigating water or subsoil.

In using large heads of 6 to 10 cubic feet per second, it is best to divide the stream between several borders so that about one hour will be required for the sheet of water to traverse the field. The amount taken up during this time will be determined by the composition and mechanical condition of the soil. The skilled irrigator will divide the flow and vary the length of time the water remains on the ground in such a manner that the proper amount will be retained.

When hay is the principal crop sought, the soil should absorb at least 3 inches of water at each irrigation. This should have penetrated within the first hour to a depth of one foot or more. If the penetration is slower than this it indicates a "silted up" or compact condition of the soil which is harmful. Such lands should be loosened by a thorough cultivation with the disk or spike-tooth harrow.

The amount of water usually applied to alfalfa in the Salt River Valley is 4 to 4.5 acre feet a year Up to a limit of 6 to 7 acre feet a year the yield increases with the amount of water received. Such heavy applications of water, however, are usually not profitable. In the case of seed crops these larger amounts are harmful.

Excessive irrigation is injurious to alfalfa in any stage. It soon dies out in swampy land whether this be caused by poor drainage, the rise of the water table, or too heavy and frequent irrigations. The necessity of thorough drainage and the depth of the water table have already been discussed. As a result of excessively heavy irrigations, low places in the field due to improper leveling, the breaking of ditches, or heavy rainstorms, portions of alfalfa fields are frequently flooded and remain under water for a considerable time. Where the plants are submerged not more than 12 hours, permanent injury seldom results, but when water stands for two or three days over the field, alfalfa will be killed.

SEDIMENTS[1]

All lands watered from streams receive a deposit of more or less silt at each irrigation. During seasons of flood the amount is many

1. The discussion of sediments here given is condensed frwa Bulletin No 53 of this Station. Irrigating Sediments tod their Effects upon Crops, by & H Forbes (1900).

times greater than at the low stages of flow. The following table gives the extreme and average amounts of sediments contained in the waters of the Salt, Gila and Colorado rivers:

SILT FOUND IN RIVER WATER

	Minimum silt per acre ft of water m tons	Maximum silt per acre ft of water in tons	Average silt per acre ft of water in tons	Thickness m inches of the sediment in four average acre ft. of water as agricultural soil
Gila at Florence	11	128 03	19 23	46
Salt at McDowell	05	12 95	1 20	03
Colorado at Yuma	1 14	44 42	9 62	23

That these sediments contain considerable fertilizing value is shown by the following table *

FERTILIZING CONSTITUENTS OF RIVER SILTS

Fertilizing constituent	Gila River, pounds per acre ft			Salt River, pounds per acre ft			Colorado River, pounds per acre ft		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Potash (K_2O)	2621 8	2 7	214 3	267 4	4 1	18 0	444 6	14 7	1131
Phosphoric acid (P_2O_5)	352 1	1 8	36 9	73 1	1 5	6 6	43 6	2 3	10 0
Undissolved nitrogen (N)	172 3	98	28 1	69 4	10	5 5	38 3	0	4 8

Of these fertilizing constituents potash and phosphoric acid are already present in Arizona soils in sufficient quantities. Nitrogen, however, is usually deficient. Whatever amounts of this element are added in the silt deposits, therefore, form a welcome addition, but it must be remembered that the yearly average of from 5 to 28 pounds *is* much less than the amount usually removed in a single cutting of one ton of hay. By no means are all of the sediments contained in the river flow carried upon irrigated fields, "With gentler gradients and slackening motion of the water, the heavier portions are soon dropped in canals and lateral ditches." "While we calculate, therefore that 4 average acre feet of Colorado river water at Yuma carry sediment to make a layer of soil about one-fourth of an inch thick each year, the larger portion of this amount is actually deposited within the ditches or concentrated upon much

less than half of the ground irrigated. From these facts we may conclude that the fertilizing value of river sediments is of but little immediate consequence to the alfalfa grower.

Since the coarser and more sandy part of the sediment is dropped in the lessening currents of the canals and field laterals, it is only the finest silt and clay that is deposited upon the fields. Such deposits form a more or less impervious surface layer through which the water penetrates slowly. These accumulations are thickest at the upper ends of the fields in the vicinity of the head ditch from which the muddy water is diverted, and are least at the lower ends. The lack of permeability of these silt-blankets may be easily demonstrated by an examination of the soil shortly after irrigation. In certain instances this has been found dust-dry a very few inches below these sedimentary deposits while at the lower ends of the same fields, with but little accumulation, the same irrigation has penetrated several feet. The depreciation in yield caused by silt-blankets may be attributed both to a lessening supply of water and of air to the roots." The amount of loss occasioned in this way varies from a very little to as much as two-thirds of the normal crop, or 3 or 4 tons of hay per acre on a strip of ground extending out for 200 or 300 feet from the head ditches. The width of these damaged areas depends upon the fineness of the suspended matter in the water. In the case of mine tailings, which are frequently discharged into rivers, the waste materials are in a most minutely divided condition and are, therefore, carried by the water almost as long as it Has motion. They are finally deposited only when the water sinks into the soil in irrigated fields. These sediments arc even more impervious to water than the silt usually deposited from muddy streams. In order to estimate the total depreciation in the yield of alfalfa in irrigated sections due to these silt-blankets, three representative fields near Yuma, Phoenix and Solomonville were selected, divided into plots from their upper to their lower ends, and the weight of hay from each plot taken for one cutting. Comparing these weights with the maximum yield at the lower ends of the fields* where the least sediment had accumulated, the percentage of depreciation in yield due to the silt-blanket was estimated as follows:

Near Yuma, 2nd cutting, May 19, 1905, depreciation 6.3%
Near Phoenix, 3rd cutting, July 10, 1905, depreciation 9.7%
Near Solomonville, 2nd cutting, June 23, 1905, depreciation 27.6%

A fourth field near Mesa, Arizona, irrigated with clean pumped water produced its heaviest crop next to the ditch, where, sedimentary deposits being absent, more thorough irrigation was secured. Cultivation by means of the disk and spring-tooth harrow, is the best available means of handling these accumulations in alfalfa. This treatment breaks up the blanket and allows better penetration of water and air into the soil.[1] The spike-tooth disk harrow will also be found useful in breaking up these sedimentary impervious layers. Cultivations should be made either in the fall or shortly after a cutting.

CULTIVATION

Alfalfa fields will sometimes give profitable yields for years without any attention save the irrigation which they require and the harvesting of the successive crops as they mature. Like other crops, however, this also responds in most cases to cultivation. The soil becomes packed by the repeated passage over it of harvesting machinery, draft animals, the trampling of pastured cattle, heavy rains, and by the partially impervious silt-blanket deposited from muddy irrigation water or mine tailings. Not only do such soils take up the irrigating water slowly but they lose it rapidly by evaporation, thus reducing yields by reason of the lack of moisture under conditions of irrigation which should amply provide for all of the needs of a heavy crop. Moreover, these packed or silted up soils are poorly aerated. The roots of the alfalfa being insufficiently supplied with oxygen are unhealthy and susceptible to the attacks of any harmful fungus which may be present. The nitrogen-fixing bacteria which live in the roots of the alfalfaare also probably deprived of a proper supply of air and are therefore unable to thrive and enrich the soil. Another reason for cultivation is the destruction of weeds and grass which spring up from time to time. If the ground has been well prepared before planting so that the alfalfa becomes well established before the weeds appear, the former will have deep and strong taproots, whereas the roots of the weeds and grasses will be for the most part near the surface. In this condition they may be torn out with the disk, spike, or spring-tooth harrow without in any way injuring the stand of alfalfa. Fall cultivation also destroys large numbers of the eggs of grasshoppers and other predatory insects; and exposes numerous hibernating larvae and adults of injurious

1, Forbes R. H. Cultivation of Alfalfa. Arizona Agr. Exp Sta. Timely Hints for Farmers No. 61, (1906).

species such as the alfalfa butterfly. Cultivation, moreover, incorporates into the soil the leaves and stems of alfalfa wasted in haying, thereby adding humus and improving the mechanical condition. Finally, the loosening of the soil, and breaking up of silt-blankets promotes aeration, permits the better penetration of irrigating water and reduces evaporation by destroying the perfect capillary conditions existing in a compact surface. The tools usually employed for this work are the ordinary disk-harrow, the spring-tooth harrow and the "alfalfa renovator" or spike-tooth disk. The first and last of these are generally preferred since with them the soil can be loosened to a greater depth. The disk-harrow is set nearly straight so that the soil will be lifted but not entirely turned over. This will loosen the ground and shallow rooted weeds without cutting many of the alfalfa crowns. The machine should be weighted sufficiently to make it penetrate at least 4 inches, If the ground is very weedy it may be necessary to cross disk and then follow with a drag harrow to complete tne destruction of the weeds. This can be done without serious injury to the alfalfa. The alfalfa renovator has the advantage over the disk that with it the ground can be more thoroughly loosened with less injury to the alfalfa plants. Where one is the owner of sufficiently large fields to warrant the purchase of this special tool, it is to be recommended above others for the purpose of alfalfa cultivation. More recently the Deere alfalfa cultivator is coming into general use. This cultivator somewhat resembles the spring-tooth harrow, the oval, crescent shaped, reversible teeth being mounted on springs in such a manner as to slide around and between the alfalfa plants with very little damage to them.

INTERCULTURES

Wintergrain: It is a very common practice among some of the most successful growers of alfalfa to sow winter grain on the fields as an intercultural crop. The advantages urged for this practice are, (1) more winter pasturage, (2) increased yield of the first hay crop in the spring, (3) choking out of early weeds which reduce the quality of the first hay crop, (4) and the pasturage as well as early hay containing an admixture of grain is less liable to cause bloating than pure alfalfa,

The grains most frequently used are Texas Red oats, wheat of rye, and barky. About one-third as much seed is sown as would be used for a full stand of grain in pure culture. This would call for 20 to 25 pounds of oats or barley and 25 to 30 pounds of wheat

or rye. In late sowing, more seed should be used, as the plants will stool less. Where winter feed is the primary object, the sowing may be made as early as September, just after the next to the last cutting. On the other hand, the seed may be sown immediately after the last cutting or even later following a season of fall pasturage, whereby the stubble is eaten off close enough to allow the use of the disk and drill. More or less winter pasturage may be secured when the planting is not later than November 1.

It is the practice of some farmers to sow the seed first, then give the field a thorough cultivation with the disk or renovator and follow with an irrigation. Others prefer to disk the land, sow with a press drill and then irrigate. The writer has seen some good stands secured by simply following a thorough irrigation with the press drill, but this is not be advised since both the alfalfa and the grain will miss the beneficial effects of the cultivation.

Where there is a perfect stand of alfalfa and little trouble from weeds in spring, it is doubtful whether it pays to sow winter grains. Under these circumstances the total yield is very little, if any, increased. On the other hand, where the stand is thin, especially where thin seeding is practiced by those who make a specialty of seed growing, the interculture of winter grains is profitable. By two or three diskings in summer and the use of winter grains, good yields may be secured from old stands of alfalfa for several years after they would otherwise have become too thin and weedy to be profitable.

Thickening up a stand: This is seldom successful. Where the stand is so thin that the yields are no longer profitable it is better to plow up the whole field. The cause of this is that where the stand of alfalfa is poor, weeds soon creep in. In attempting to reseed among the old plants it is almost impossible to prepare a perfect seed bed and destroy the weeds to such an extent that the weak alfalfa seedlings can compete with them. The disk cannot be used to destroy the weeds and if one attempts to keep them down by frequent mowing he will be wasting and destroying the yields of the older plants present. A few cases of successfully thickening up a thin stand have been observed. The practice most likely to succeed is to sow after a thorough cultivation in the fall. The seed may be broadcasted, harrowed in and then irrigated; or else planted with the press drill as soon after a thorough irrigation as possible without miring the teams. The latter method is most advisable. This alfalfa should not be pastured during the following winter, as the trampling will kill out the young plants.

PASTURING

There is a decided difference of opinion among successful growers as to the advisability of pasturing alfalfa. Some maintain that it should never be pastured, while others are equally sure that much additional and valuable fall and winter feed may thus be obtained without appreciably reducing subsequent yields of hay. Certain heavy soils are very susceptible to injury by the trampling of cattle. Under grazing they soon become packed and hard, rendering the aeration poor and the penetration of water, already too difficult, nearly impossible in amounts sufficient to support good crop yields. This is especially the case when such soils are trampled by grazing animals while still damp from recent irrigation. Especial care should therefore be exercised to allow stock on stiff lands only when the soil is dry. Sandy, light lands are not so liable to injury from trampling but even these should not be grazed while wet.

When the range grasses fail in fall and winter, good prices can be secured for alfalfa pasture. These vary from $1 to $3 an acre for 1 to 4 months, depending upon the amount of growth originally on the field and the number of cattle that a given area can support. A fair price per month for each head of cattle on good alfalfa pasture is $1.50 No rule can be given as to the number of cattle per acre that should be pastured or the length of time they should be allowed to remain. Ordinarily one acre may be expected to furnish pasture for two animals for two months but this will depend entirely upon the amount of growth on the field when they are first put on, the stand of alfalfa, whether or not grain has been sown to supplement the alfalfa, and the nature of the weather which will determine the amount of winter growth.

When the demand for alfalfa pasture in winter is strong and the price consequently high, many farmers are tempted to allow their fields to be overgrazed. The alfalfa crowns are therefore eaten clean of herbage and exposed to the cold of winter and the injurious effects of excessive trampling. The result is that the stand is much reduced, the vitality of the plants lowered, and an opening made for the entrance of weeds. The writer attributes the over-running by bermuda grass and wild barley of a large number of alfalfa fields in the Salt River Valley to overgrazing. Such results have led many cautious farmers to withhold all winter grazing.

To withstand even an Arizona winter properly, the alfalfa crown should be protected by a tuft of more or less green herbage. Whenever this is completely eaten away we may be assured that the plant

has been overgrazed and will be injured. It makes very little difference whether a given area has been pastured by a large number of cattle for a few days, or by a few cattle for a greater length of time, the farmer must judge by the condition ot the field the limit to which it may be safely continued. The green herbage which should be allowed to cover the crowns of alfalfa plants throughout the winter not only serves as a protection, but also aids in storing up in the large taproots a reserve supply of material whereby the plants arc able to put forth an early and vigorous growth the following spring. One farmer, tempted by the high price of alfalfa pasture, allowed his fields to be overgrazed during the winter of 1909-10. That spring he reported a loss of fully 50 percent on the yields of the first two cuttings of hay. Not only did he suffer this temporary loss, but the stand on the whole area was doubtless injured to such an extent that these fields will never give as profitable yields again until they have been plowed up and reseeded. On the other hand, the writer knows of fields of alfalfa which have been conservatively grazed for ten years with practically no injury. Experiments carried out by Wilson[1] during 1907 showed that the close grazing of alfalfa by sheep from April 1, until the close of the season, destroyed one-half the stand. He ascribed this loss to the scant covering left upon the ground whereby the sun and wind not only dried and cracked the soil but injured the constantly exposed crowns, many of which ultimately perished. On farms where sheep are kept, he therefore suggests that the fields be grazed in rotation. This allows time for recovery, and opportunity to counteract by cultivation, the evil effects of the trampling. This same advice may be extended to those who keep dairy cows and pasture them on alfalfa throughout the year. To avoid damage it is better to take the stock off the field before it is eaten clean; and if there be spots left, due to uneven grazing, these may be run over with the mower in order to give the whole field an even start.

During fall and winter the writer would prefer the practice of putting on sufficient stock to consume the surplus feed in 25 to 30 days. The field may now be thoroughly disked to overcome the effects of the trampling and then irrigated to stimulate the plants to renewed activity. During the remainder of the winter at times of mild temperature, the plants will recover sufficiently to put forth an early and vigorous spring growth. Excluding semi-arid regions in which alfalfa is grown without irrigation, it is a well-known fact that grazing secures less of actual food from the ground than either soiling or the production of hay. It is therefore usually inadvisable to pas-

1 Wilson, F. W.....Kept of Dept. of Animal Husbandry Am Agr Exp St* Rept 18, (1907) p 223

ture alfalfa during the summer months, pasturage being advised only for the purpose of making use of surplus and waste growth that cannot be utilized for hay in late fall and early winter. Even in these cases it must be practiced with caution, and followed by cultivation in order not to leave permanent injury to the stand and vigor of the alfalfa.

SOILING VERSUS SUMMER PASTURAGE

A dairyman in the Salt River Valley reports that 10 acres will support 30 dairy cows by soiling and only 20 by pasturing. In another instance 16 head of dairy animals were kept from March to August inclusive on 3.5 acres of alfalfa by soiling. On September 1, the same stock was turned on 10 acres of alfalfa, then 16 inches high. This entire pasture was grazed so closely within six weeks that the stock had to be removed.

Experiments with beef cattle near Glendale have shown that where soiling is practiced, 100 steers will eat 1 to 2 acres of alfalfa a day. On the same farm it required 80 acres of alfalfa pasture to carry 110 steers through the growing season.

An acre of mature alfalfa that would produce 1 ton of hay carries approximately 4 tons of green stuff. Now, 75 pounds of green alfalfa is ample feed for a large steer for one day. One acre of alfalfa should therefore feed 106 animals for one day. Estimating 35 days as the average required time to mature a crop and allowing a small amount for wastage, we can safely assume that 35 acres of good alfalfa should keep up 100 steers throughout the growing season. This is about double what could be expected by pasturage.

The extra labor involved in soiling can be reduced by the con* struction of feeding lanes adjacent to or running through the fields. Practical farmers who have tried both methods in Arizona are convinced that even with our high priced labor, the greater yield of foodstuff per acre, the better condition in which the fields are maintamed and the increased flow of milk in the case of dairy animals, make the practice of soiling economically more profitable and satisfactory than summer pasturage. Soiling is no more injurious to the stand of alfalfa than the production of hay. On tifce other hand, no field can maintain a stand longer than 2 or 3 years when subjected to summer pasturage. Alfalfa should be cut far soiling at approximately the same stage as it is cut for hay. This point cannot be regarded in the first soilage crop in spring, but after the field is

cut over once the different parts will come to maturity successfully so that the alfalfa can be cut when about one-third in bloom or when the new basal shoots start, as is the practice in the making of hay.

BLOATING

When alfalfa is growing vigorously and is very succulent, when it is wet with rain or dew, or has been strongly nipped by frost, it is liable to cause bloating. Especially is this true where hungry animals are allowed access to it. There is never absolute safety in pasturing cows or sheep on alfalfa but where the proper precautions are followed the losses are not equal to the gains made from the pasturage. The animals should first be given all the hay that they can be induced to eat and then filled up with water, so that they are not hungry or thirsty. If they are then turned on the alfalfa, preferably about midday, they will eat very little at first. After this they should be allowed continuous access to the pasture both day and night. Under these conditions, never being allowed to become hungry, they do not gorge themselves and are therefore in little danger of becoming bloated.

Wing[1] advises the following treatment for bloated animals: "Very often animals slightly bloated, recover unaided. If, however, there is considerable distress the attendant should go at once to their aid. With sheep, take a stick about 2 inches in diameter or a large cob, insert it between the jaws, thus keeping the mouth open, raise the head and gently press the side between the knees. This will usually result in causing the gas to be belched off. A half pint of raw linseed oil, with a teaspoonful of turpentine added, is a relief and the same mixture in larger doses relieves cattle.

When it is evident from the extreme tension of the paunch that this will not be enough to save the animal, recourse must be had to the trocar. At a point on the left side, the walls of the paunch and the skin unite in the cow and are close to each other in the sheep. Here an incision may be made without causing the animal much pain, and a tube put in to aEow the gas to escape. The trocar isbetter than the femife, as it opens a small hole and there is no danger of opening one too large; then when the point is withdrawn, the tube remains in the opening through which the gas may escape. After using the trocar, one should liberally disinfect the wound with turpentine or some carbolic disinfectant."

1. Wing, Jos. E. Alfalfa in America. (1909) p. 341.

DURATION

Alfalfa fields have been known to remain productive for more than 50 years without reseeding. Such a long occupation of the land by one crop, however, is rare and seldom desirable. Since alfalfa does not spread by runners, suckers or the rooting of branches, when a plant dies or is killed, its place is left vacant unless taken by a volunteer seedling Such natural reseeding is uncommon and, as already pointed out, is difficult of success even artificially. As the plants die out, the vacant spaces are more or less occupied by the increase in size of those remaining. When, at length, the alfalfa becomes so scattered that the ground is not fully shaded at maturity, weeds soon gain a foothold. The yield and quality of the hay now begin to decline and so continue until the field ceases to be profitable. With reasonable care and culture an alfalfa field should continue to give profitable yields for 10 to 15 years. Alfalfa does not fully mature and reach its maximum productiveness until it is about 3 years old. Unless, therefore, conditions are such as to demand a shorter rotation, it is seldom advisable to destroy a good stand of alfalfa under 7 to 10 years. Where, on the other hand, alfalfa is the most profitable crop that could occupy the land, as is the case in many parts of Arizona, there is no reason whatever for destroying a good stand of alfalfa at all so long as the yields are satisfactory. In some sections where the land is badly infested with bermuda, Johnson grass or other noxious perennial weeds, it will be necessary to practice short rotations with cultivated crops such as cotton, sugar beets or corn. (See Weeds, p. 307.)

FERTILIZERS

Practically all Arizona soils contain sufficient mineral plant foods to produce good crops for an almost indefinite period. They are frequently deficient in nitrogen and humus. The growing of alfalfa is itself one of the best means of adding these elements to the soil. The application of barnyard manure and other nitrogen and humus-bearing fertilizers is seldom necessary for alfalfa, except occasionally for the purpose of improving the mechanical condition of raw desert soils or certain compact or "slick" spots, which, as already described, frequently occur. While stable manure and other waste products may be of some value on alfalfa, it is the opinion of the writer that it would be more profitable to apply such of these as are produced on the farm to other crops, preferably orchards, vegetables, grains, or sugar beets.

HARVESTING AND STORAGE

HAY

TIME TO CUT

The harvesting of the hay crop should not be delayed, except for bad weather, when any of the five conditions given on page 260 appear. The many hundreds of years during which alfalfa has been regularly cut for forage, have adapted it to this practice. It will maintain a stand for a greater length of time and be more vigorous when regularly cut than when it is neglected or allowed to go to seed. The plants should be allowed to grow so long as the stems remain succulent, and increase m height continues. When, however, the upward growth ceases and the plants begin to bloom, or growth is checked and the stems mature and become woody without blooming, as is often the case m late fall or when the plants are diseased, the field should be cut. If delayed at this time, the new growth will be slow in starting and the next crop light in yield. If cut too early, on the other hand, the yield is light, the hay is more likely to cause bloating or scouring of stock and the vitality of the plants is reduced. In ordinary practice the maximum yield and quality of hay is obtained where the crop is regularly cut when about one-fifth to one-third of the plants are in bloom, or when new shoots begin to appear at the bases of the stems. Experiments by Foster and Merrill[1] show that, whereas, other conditions being similar, the yield from a given cutting increases until the blooms have more than half fallen, when the whole season is taken into consideration, the greater total yields are secured when cutting is made in early blooming stage. This is caused by the fewer cuttings, slow recovery, and low yields in the latter part of the season from the late mown fields, as shown in the following table:

EFFECT OF TIME) OF CUTTING ON YIELD OF ALFALFA[2]

Time of cutting	Yield 1st cutting lbs	Yield 2nd cutting lbs.	Yield 3rd cutting lbs	Total yield for season lbs.
First bloom.....	4307	3565	2847	10719
Full bloom.....	4338	3296	2105	9829
Half fotoomfe fallen,.....	5014	3801	286	9101

1. Foster, L, and Merrill. X* A. Alfalfa or Lucern, Utah Agr. Exp. Sta. Bul. No. 61 (1899).
2. Utah Bul 61 (1899), p. 166.

These experiments are also corroborated by results at the Kansas Experiment Station.[1] The decline in the protein content of alfalfa hay from first to full blooming is set forth in the following table:

THE EFFECT OF TIME OF CUTTING ON THE COMPOSITION OF ALFALFA HAY[2]

Stage	Crude protein
10% in bloom	18.50%
50% " "	17.21%
100% " "	14.43%

The high protein value of the earlier cutting is an advantage in the feeding of cattle, especially dairy cows, but for horses such rich

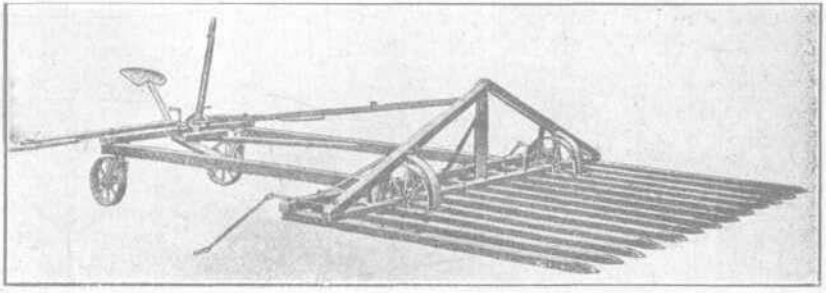


Fig. 4.—Buck or sweep-rake.

food has a tendency to purge. When, therefore, the hay is to be fed to draft or driving animals, it should be allowed to reach nearly mid-flower before cutting; but care should be taken to cut before the new growth starting at the bases of the old stems gets long enough to be clipped by the mower. If this occurs, recovery of growth is greatly retarded and the subsequent yields for that year are seriously affected.

CUTTING AND CURING

The mowers should begin in the morning as soon as the dew is off, if such has fallen. Machines cutting a swath of 3.5 to 7 feet can be had to fit the purse and needs of the farmer. The larger machines with a heavy draft are used on extensive farms where the land is level and smooth. As soon as the leaves are well withered, but before they have become crisp, the hay should be raked into

1. Kans. Agr. Exp. Sta. Bul. No. 55 (1908), p. 239.
2. Kans. Agr. Exp. Sta. Bul. No. 155 (98), p. 284.

windrows If the leaves are allowed to dry into a crisp before raking, many of them will shatter off and be lost in this operation, and, moreover, the subsequent curing of the hay in the windrow or cock is not so satisfactory. The reason ascribed for this is that the evaporation from the withered leaves serves as a pump to extract water from the stems. If allowed to dry into a crisp quickly their condition is such that they are no longer able to do this. The stems therefore cure slowly and the hay maker must either allow the leaves to become so dry that they are for the most part lost by shattering, or else the stems must be put into the bale or stack with such high moisture content that injury by heating or moulding will occur. If the cut alfalfa is so thick on the ground that the exposed leaves become crisp before the covered ones wither, the field should be gone over with a tedder. In the dry air and bright sunshine of our Arizona summers, however, a tedder is seldom necessary.

The hay is gathered into windrows by either the dump or the side-delivery rake. The row of teeth in the former is set at right angles to the line of draft. The hay is therefore gathered and held until released by the hand, foot or automatic dump In the side-delivery rake, the row of teeth is set at an angle to the line of draft. The hay is gathered, carried forward with a rolling motion and delivered in a constant stream at one side. In the passage from one end of the field to the other and back, two sweep widths of the rake are thrown together into a single windrow. The advantage claimed for these machines is that the windrows they make are more loosely thrown together than the windrows made by the dump-rake. When the crop is short and light, the windrows made by the side-delivery rake are liable to be too thin, especially in uneven parts of the field. Too much of the hay is therefore exposed to the direct rays of the sun and is liable to bleach or become so crisp that the leaves are lost in subsequent handling. From the windrow, alfalfa should be ready for stacking in two days and for baling in three days. The length of time required for curing will, of course, depend upon the temperature, the intensity of sunshine and the amount of wind. A good rule is that hay is ready for stacking when water can no longer be twisted out of a wisp of stems held between the hands. It is not ready for baling, however, until such twisting will cause the stems to break.

Many farmers prefer to cure alfalfa in the cock rather than in the windrow. This method is more suited to the intensive farmer and to situations or times when there is danger of showers during the haying season. Hay in the cock resists the effects of rain better than

in the windrow, and is, moreover, in position to be protected by canvas or paper caps. Where the price of hay is high and the curing must be made in a rainy season, hay caps are frequently used with much profit. Caps made of canvas are preferable since they are more durable and are not blown off so badly by strong winds. Such caps 40 inches square, weighted at the corners, can be had manufactured especially for this purpose and sold at about 12 cents each.

The hay is usually allowed to remain in the windrow for one day, or until it is about half dry. It is then bunched with the rake or by hand and thrown into cocks with the fork. Hay cocks are preferably as tall and narrow as possible so as to allow better circulation of air around and through them. Here the hay may remain three, four or more days until it is thoroughly cured, whereupon it may be baled or stacked directly from the cock.

The general principle to be kept in mind is that the hay should be cured with as little exposure to direct sunlight, dew or rain as possible. Too much direct sunlight bleaches the hay, detracting much from its appearance, palatability, and, to a certain extent also, its feeding value. Hay should be gotten into the stack or shed with the least possible handling, since at each operation some of the leaves are shattered from the stems and lost. While the leaves make up but one-half of the weight of the hay, slightly over 70 percent of the entire protein content is contained in them. The importance of so handling the hay as to retain the leaves without loss is therefore easily recognized. Experiments at the Colorado Station[1] show that under ordinary farm conditions, the mechanical loss by shattering of leaves and by hay left on the ground varied from 5 to 10 percent. Loss in dry matter due to cloudy weather or rains varied from nothing to 26 percent. These losses were not only caused by the wasting of material, but also by decomposition due to fermentation and by the leaching of soluble substances from the hay itself. Headden[2] shows the effect of rainfall on the food value in an example where hay cut on May 28 could not be sufficiently cured for storing until June 12 on account of rainy weather. During most of this time the sky was clouded and the total rainfall was 1.76 inches. Samples of the original hay, artificially and perfectly cured without loss, contained 18.7 percent of protein while that exposed to the weather for two weeks contained only 11.0 percent of this most valuable of its food elements. Even a light rain destroys that bright green color so characteristic of first class alfalfa hay.

Moisture from rain or dew which wets the outside of the stems

1. Gayle, W. W. Farm Notes, Colo. Agri. Exp. Sta. Bul. No. 37 (1900), p. 4.
2. Headden, W. P. Alfalfa, Colo. Agr. Exp. Sta. Bul. No. 36 (1896), p. 12.

and leaves is more apt to cause damage than the same amount of natural water contained within the plant. This external moisture favors bacterial action and the growth of various molds. It is, therefore, highly important that there should not be the least dampness from dew or rain upon the hay when it is stored.

HAULING, STACKING AND STORING

When the fields are small and labor plentiful, alfalfa may be loaded on the wagon by hand and hauled to the stack or shed. Here various means of unloading have been devised to save time over the old method of lifting hay by the hand fork. Slings made from a network of ropes may be placed on the load at intervals, which being taken up successively by block and tackle at the barn, unload the hay very swiftly. Double grapple hooks are also made which will take up a large quantity of hay at once and lift it into the shed or onto a stack. The unloading tool in most common use in Arizona is the type of Jackson fork manufactured in California. This is simple ia its structure and operation, and may be used either with the derrick or with pulley and track.

Several forms of loaders are on the market designed to take the hay directly from the swath or windrow and deposit it on the wagon. Only the latter type is of interest to Arizona farmers, since here it is always advisable to cure the hay in the windrow or cock to avoid bleaching and the loss of leaves by shattering. Very few of these are in use in Arizona at the present time and there is a diversity of opinion among those who have used them as to their practical value

Many of those who handle hay on a large scale find it most profitable to draw the hay directly from the windrow or cock to the stack by means of a sweep-rake, buck-rake, or "go-devil." These are in use only where the hay is to be baled or stacked, in or very near the field where it is grown. They are not suited for carrying loads more than a short distance. These tools consist essentially of a row of long horizontal teeth which slide along the ground and pick *up* the hay. At the back is a suitable frame or rake to catch and hold the load of hay. The draft team, consisting of two to four horses, is hitched at the sides in some forms, and at the rear in others. In the cheaper and older forms, the teeth and load slide on the ground at all times, but the better types are fitted with wheels and arrangement is made to lift the weight from the ground as soon as the load is secured. In this type the loss of hay and the draft is lighter while passing to and from the stack. Many farmers complain

that these tools do not take up hay clean, but when this is the case it is an easy matter to pick up and bunch with an ordinary dump-rake whatever waste there is left along the windrow or row of cocks.

Wherever the hay is to be stacked in the field, shed or barn, some form of mechanical lift is a profitable saver of time and labor. The double grapple fork, hay sling, or Jackson fork with pulley and track for use in barn or shed have already been mentioned. Among the simplest devices for stacking is the derrick set up on runners or wheels and provided with a fork for lifting the hay. A rope and pul-

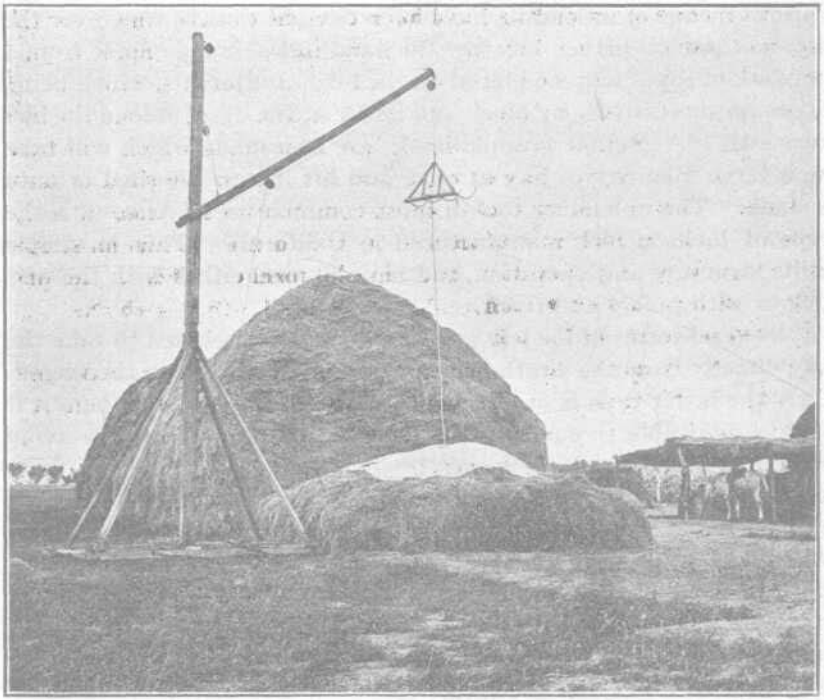


Fig. 5.—A simple and effective alfalfa stacker, set on skids and provided with a Jackson fork.

ley is arranged for a horse as lifting power. A line is attached to the arm of the derrick whereby the man on the stack may bring the load to the desired position and drop it. The derrick is usually set at a slight angle so that the arm swings back to its original position for reloading when released.

In another form of cheap stacker, two long uprights are set in the ground about 10 or 15 feet apart and inclined together at the top where they are firmly bolted. Two other similar uprights are located at a distance from the first equal to the length of the

stack desired. A strong wire rope is now brought over the tops of the frame thus formed, drawn tight and anchored firmly in the ground at either end. Where the rope passes through the crotch of the uprights it must be fastened securely to prevent it from slipping and pulling the two sets of uprights together at the top. The horizontal part of the wire rope now forms a track on which a double pulley may run. Upon this pulley the lifting fork is mounted and operated in the same manner as for the hay derrick. The load of hay is halted beneath the rope track where it is picked up by the fork, carried along the rope and deposited on the stack. Various other forms of mechanical stackers have been devised. Most of these are especially designed for taking the hay directly from the sweep-rake or go-devil, elevating it and dropping it on the stack. Descriptions and prices of these may be obtained from dealers in farm machinery.

A large proportion of the alfalfa hay produced in Arizona is stacked in the open. This procedure would be fraught with much loss in any section with a less dry and equable climate. Alfalfa hay sheds water probably more ineffectually than any other forage crop. Cuttings made previous to or during our summer rains and stacked in the open are especially liable to injury. The writer knows of several instances where large, well built stacks of alfalfa have been badly wet by a single, heavy, summer rain. When once wet it is very difficult to open up a stack and recure the alfalfa. Such losses coming when they are least expected, make it an open question whether it is not always better to provide a shed in which the alfalfa may be stored.

The advantages of stacking alfalfa as compared with other methods of storage are, (1) the rapidity with which it can be carried out on a large scale in seasons of rush work, (2) the cheapness of this mode of storage, (3) the small amount of handling it requires and hence the minimum of loss from shattering, and (4) the convenience with which it may be fed to cattle.

In seasons of rush work on large farms it would be almost impossible to bale the hay as fast as it is harvested and cured, without leaving it in the windrow or cock so long as to become unnecessarily dry or to expose it to the danger of injury by uncertain summer showers. In cases where the hay is to be baled, it is therefore usually stacked temporarily until the baling can be done.

Where hay is to be fed on the farm, it is unnecessary to go to the trouble and expense of baling it. When, however, it is left exposed in the stack for the whole season, more or less damage is almost

certain to result. The saving of this damage will usually more than pay interest on an investment in a good hay shed.

When, on the other hand, the hay must remain in the stack for some time, it is necessary that the stack be carefully built. In order

Fig. 6.—Alfalfa hay wasted by stacking in the open. Experiments have shown that the average loss in food value of alfalfa kept in an unprotected stack over that stored in a barn or shed is 20 percent. In some years the loss may be as low as 10 percent, while in years with much rain more than half of the hay may be spoiled.

Fig. 7.—Hay shed 96 feet long, 50 feet wide and 16 feet high at the eves. This shed holds about 650 tons of baled alfalfa or 200 tons loose. Its cost in the Salt River Valley, was approximately $1000.

that it shed water to the best advantage and give the least percentage of waste, the stack should be as tall as possible in proportion to its width. This, of course, will depend upon the quantity of hay to be stacked and the height of the available derrick or stacker. Stackers which will raise the load as high as 26 to 30 feet are not uncommon. A stack 25 feet high should not be over 18 or 20 feet in width. Care should always be taken to keep the center well filled and

tramped in order that as settling takes place there will always be maintained a middle ridge to turn away rain rather than a depression to collect it. Since, however, alfalfa hay turn swater so poorly, it is always best to cap the stack with a heavy canvas, or in the absence of this, a layer of grass or sorghum hay a foot or two thick.

As a result of careful experiments in Colorado, Cooke[1] concludes that the average loss in food value of alfalfa kept in the stack, over that stored in a barn or shed is 20 percent. In favorable years the loss may be as low as 10 percent, while in years with much rain, more than half the hay may be spoiled These losses emphasize the economy of storing alfalfa in a well built shed rather than in the open. Such a shed, holding 100 tons of loose hay or 350 tons in the bale, has been built in the Gila Valley for about $600 Now, using the minimum loss of 10 percent on loose hay, we have an annual saving of 10 tons worth $120 as a return for the expenditure on the shed, Basing the calculation on baled hay we would find an even greater saving. One hundred and twenty dollars would repay the capital in five years and leave a shed which certainly should be in good condition for an additional ten years. Looked at in another way, the $120 would pay an interest of 8 percent on $600 and leave a net income of $72 a year. A good shed is thus not only seen to be a paying investment in ordinary years, but it is, moreover, an insurance against heavy loss in seasons of exceptional rainfall.

STORAGE SPACE REQUIRED FOR HAY

Baled hay occupies 140 to 160 cubic feet per ton, the average being about 150 cubic feet The size of the bale vanes slightly with the different sizes and makes of presses A very common size is 15 x 18 x 37 inches Such a bale will usually weigh 70 to 80 pounds according to the pressure used in packing, and the moisture content of the hay. Bales weighing 100 pounds are put up in certain sections, especially Southern California, but the Arizona market prefers the smaller size. Loose alfalfa hay freshly stacked occupies about 512 cubic feet per ton, when stacked five or six months, 422 cubic feet per ton; stacks of medium size, a year or more old, 342 cubic feet per ton, and large, old stacks, 216 cubic feet per ton. In calculating the capacity of a shed for loose hay, the higher figure of 512

1. Cooke, W W. *titam* Notes. Colorado Agr Exp Sta Bul No 57 (1900), p 6

cubic feet per ton should be used, since it is ordinarily filled before the hay has had time to settle to a marked degree.

The following rule for measuring alfalfa hay in the stack or mow is given by Ten Eyck[1].

"With a long stack ox rick, the usual method is to throw a line over the stack, measuring the distance in feet from the bottom of the stack on one side to the bottom on the other, add to this the average width of the stack in feet, divide this stun by 4 (which gives the side of the square), multiply the quotient by itself, and this product by the length of the stack in feet. This will give the number of cubic feet in the stack which may be divided by 512, 422, or 342 cubic feet in a ton, in order to find the number of tons. For small, low ricks, the rule is to subtract the width from the "over", divide by 2, multiply by the width, and multiply the product by the length, dividing the result by the number of cubic feet in a ton,

"There is no established rule for measuring round stacks, but this one will approximate the contents of a stack of ordinary conical form: Find the circumference at or above the base or bulge at a height that will average the base from there to the ground; find the vertical height of the measured circumference from the ground and the slant height from the measured circumference to the top of the stack, taking all measurements in feet. Multiply the circumference by itself, divide by 100 and multiply by 8, then multiply the result by the height of the base, plus one-third of the slant height of the top. The hay in a round stack is usually less compact than in a rectangular stack, hence a greater number of feet should be allowed per ton—with well settled hay, probably 512 cubic feet."

BALING

Where the distance from market necessitates a long haul or where the product is shipped by rail, alfalfa hay should be baled. The bulk is thus reduced to about two-sevenths of that of loose hay, handling is much facilitated and shed space is economized. A good press costs from $300 up, according to size and make. The small alfalfa grower, therefore, usually finds it to advantage to hirehis hay baled. In Arizona this costs from $2.00 to $2.60 a ton, varying with the locality and season. Wherever the hay can be baled from the cock or windrow, the expense of one handling can be saved. When, however, the press cannot be secured at the proper time, or when the baling cannot be done fast enough to take care of the crop, it will be necessary to put the hay

1 Ten Eyck, A M. Alfalfa, Kans. Agr. Exp. Sta. Bul. No. 155

into shed or stack. It is here very convenient to have two sheds. Under the first, hay can be thrown temporarily in the early part of the season and receive protection while it is awaiting the baler; As it is baled it can be stored in the second shed. When the summer rains are over, the last one or two crops may be safely baled from the cock or windrow and stored in the first shed for protection from the winter rains. Moreover, extra shed space is very desirable for the housing of farm machinery. The disadvantage of baling lies only in the extra cost. Where the hay is to be fed on the farm it is not worth while. When, however, the hay is to be sold in the general market, the cost of baling is more than compensated for in the increased price which may be received for it, in the facility with which it may be handled and in the marked economy of storage space when it is being held for higher prices.

SHRINKAGE IN STORAGE

Whether it is better to sell the hay at once or to hold it for higher winter prices, is determined by the relation between the shrinkage in weight during storage and the increase in price so obtained; also damage from storms, sunburn, and cost of insurance. The shrinkage in the Salt River Valley resulting from holding in stack all six cuttings from a given field until February 11, was 11 percent in 1907. In the following season loose hay from the third cutting was stacked July 20. When sold December 14, following, the loss in weight amounted to 23 percent.[1] At Yuma the shrinkage of the season's crop of baled hay, sold the following January was observed at 2.4 and 3.5 percent. In Colorado[2] the loss in weight from first cutting alfalfa stored in a shed in June and held for eight months averaged 12 percent. Loss in the stack during that time averaged 17.7 percent. Ten Eyck[3] says: "Men experienced in handling hay usually figure on about 20 percent loss in weight after the hay is put into the stack or mow until it is sold or baled." Now, estimating the summer value at $8 a ton and the loss due to shrinkage at 20 percent, the farmer would have to sell his hay at $10 a ton in order to break even. Any price secured above this could be counted as interest returns on the investment during storage, on the cost of sheds or other necessary protection, and finally as net profit. Thus, if 100 tons of fresh hay worth $8 a ton be stored

1. Wilson, F W. Report of Animal Husbandman, in Ariz Agr. Exp. Sta. Ann Rept 18 (1907), p 224.
2. Cooke, W W Farm Notes Colo Agr Exp Sta Bul. Ho, 57 (1900). p. 7-9.
3. Ten Eyck, A M Alfalfa, Kans. Agr Exp Sta Bul No, 155 (1908), p 258,

in a shed costing $600 and sold at the end of nine months for $12 a ton, the profits would be as follows: There would be at this time 80 tons of hay worth $960. The value of the fresh hay was $800. The gross profit is $160. Deduct from this the interest on $800 for nine months, $48, and on $600 for twelve months, $48, and we have left $64 as a net profit from holding.

SPONTANEOUS COMBUSTION

Hay that is damp will ferment and heat. This fermentation is a result of bacterial growth. When it takes place in the mow or stack, the heat produced cannot readily escape by radiation. The increase in warmth accelerates the bacterial growth to such an extent that the temperature of the mass rises rapidly. If the moisture is sufficient to support it, the bacterial fermentation may become so active as to raise the temperature as high as 133° F. At this temperature chemical oxidation takes place which may raise the temperature above the ignition point. If a supply of air by any means reaches the hay in this condition it will burst into flame. Such cases of spontaneous combustion are frequent in the Middle West. At one time they became so serious that the Kansas Experiment Station devoted an entire bulletin to information concerning their cause and prevention.[1]

Even though the temperature may rise above the ignition point, unless the stack is opened and a draft of air supplied, fire is not apt to break out. In such cases the hay may turn brown or even become charred and so brittle that it cannot be raised with a fork. If no air is allowed access to this mass, it will cool slowly without other injury than that to the charred and blackened hay. The actual fire, in most cases of spontaneous combustion is started by the farmer himself who, becoming alarmed on account of the vapors and odors arising from the heating stack, attempts to open it.

The only safe and efficient means of preventing injury by heating or spontaneous combustion is to see that the hay is well cured before it is put into the stack or shed. The rank and succulent growth of the first and second cuttings is much more apt to heat and burn than the later mown hay. Especial care should therefore be exercised in the early part of the season to have, not only the leaves, but the stems also, well dried out before the hay is stored,

1. Cottrell, H. M. Spontaneous Combustion of Alfalfa Kans Bul No 109 (1902).

ALFALFA ENSILAGE

The ease and slight loss with which alfalfa hay may be cured in this climate, and the eager relish with which it is eaten by all kinds of farm animals make any other manner of preserving this forage unnecessary. Even dairymen can secure green pasturage from alfalfa for their cows almost throughout the year. For these reasons the making of alfalfa ensilage is little practiced in Arizona. Alfalfa is not so well adapted to the making of silage as corn or the grain sorghums. If it is allowed to become too old or withered before putting it into the silo, it does not pack well and is liable to spoil. If cut while yet too young and succulent, it frequently becomes acid and has a disagreeable odor and taste. Still, when cut in nearly full bloom, raked at once and hurried to the silo without a chance to wither, and well tramped and weighted on top with two or three feet of some heavy, close-lying material like green corn, alfalfa may be made into an excellent silage with little loss. If it is first run through an ensilage cutter and chopped into about one-fourth to one-half inch lengths it will pack and keep better.

Such an ensilage makes an excellent food for milch cows, calves and pigs. On large dairy farms where winter pasturage is apt to fail, alfalfa silage may prove profitable.

COST OF PRODUCING HAY

A fair estimate of the cost of producing and harvesting an acre of well established alfalfa, together with the returns which might ordinarily be expected, is presented as follows:

COSTS	
Mowing five times	$ 2.50
Raking five times	.25
Hauling and stacking	6.25
Water and taxes	2.60
Labor irrigating	1.00
Cultivating (disking or harrowing)	1.00
Cleaning ditches	.50
Storing (interest on cost of shed)	3.00
	$17.10
RETURNS	
6 tons of hay in stack at $7 per ton	$42.00
2 months pasturage for two animals	6.00
Total tetunia	$48.00
Costs	17.10
Net rttruans per acre of hay	$30.90
Net profit on investment of $150	20.6 percent

When the hay is baled, these estimates may be modified as follows

COSTS	
Cost of cultivation, water and harvesting	$17.10
Baling 6 tons of hay at $2 50 per ton	15.00
	$32.10
RETURNS	
Six tons baled hay at $10 per ton .	$60.00
Two months pasturage for two animals	6 00
Total returns	$66.00
Costs .	32 10
Net returns per acre of hay	$33.90
Net profit on investment of $150 .	.22 6 percent

Where the hay can be baled from the cock or windrow the extra cost of stacking will be saved. This will probably amount to at least $1.50 an acre. Moreover, the shed space required for storage will be only one-third as great. This item will amount to $2 an acre. We thus have a net saving of approximately $3.50 an acre where the baling can be done from the windrow or cock,

If we figure the live stock and machinery of an alfalfa farm to be worth approximately $40 an acre, against which we may calculate an annual interest and depreciation of 25 percent, we still have remaining a net profit of 13.27 percent for unbaled, and 15.93 percent for baled hay.

ALFALFA AS A HONEY PLANT

A source of income from alfalfa which should not be neglected is the production of honey. Especially is this true of sections devoted to seed growing. The annual yield of honey per hive is much greater in alfalfa growing sections than elsewhere. Secretary Coburn of the Kansas Board of Agriculture, states that "Not only may the bees in alfalfa districts make double or treble the usual amount of honey, but this honey is very superior in quality, unequaled even by white clover honey of the eastern states. In favorable seasons, 100 pounds of honey per hive is no uncommon yield in alfalfa regions." Concerning alfalfahoney, Richter[1] has the followingto say: *"Honey water-white, white, light amber or amber according to the locality, character of the soil and season of the year; of excellent body and granulates within a few months after extraction. Alfalfa is the most reliable honey plant in California. The San Joaquin and Imperial Valleys are the two leading alfalfa honey districts. In the former, the first and last crops yield little, if any, honey, but the second

[1] Richter, M. C. Honey plants of California. California Agr. Exp. Sta. Bul. No. 217 (19), p. 998*

and third, when the proper climatic conditions prevail, give up a great abundance of nectar Mr. J. T. Dunn of Fresno says that four or five days of hot weather and little or no wind in the early part of June, will "bring out" the nectar, and insure a flow, whether or not wind or cooler weather comes later. In respect to the influence of the soil on the color of honey, it appears that alfalfa grown on sandy soil which does not hold water, will produce honey light in color, but in many portions of the valley where alluvial soil prevails, and where water is within four to eight feet of the surface, the color of the honey is decidedly amber In the Imperial Valley

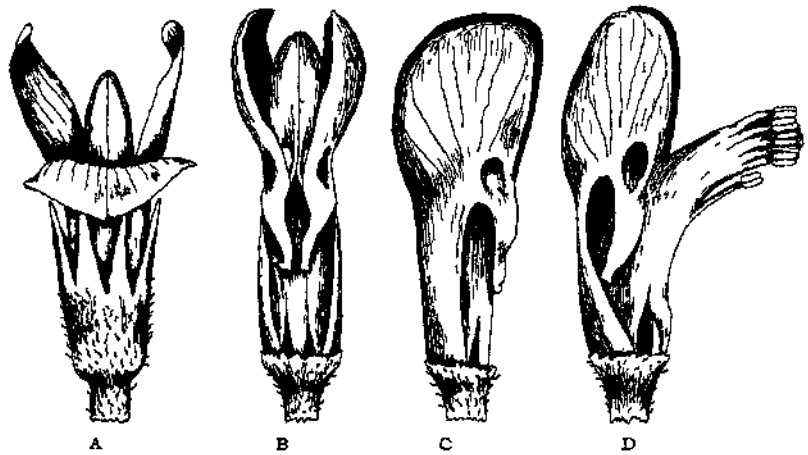


FIG. 8.—Alfalfa flowers enlarged and dissected The mechanism is here shown by which the plant promotes cross-fertilization A —Top view, entire flower B —Top view with calyx and banner removed Note the spurs on the upper backs of the wings which rest upon the central column, also the ears which extend inward from the bases of the spurs to hold the two parts of the keel together Similar ears on the keel into which these fit, extend inward and hold the central column in place C —Same as B, side view D —Same as B, side view, but showing the central column, bearing the stamens and pistil, released from the keel and bent backward The proboscis of the insect, in seeking nectar at the base of the flower, passes between the spurs and presses them apart This spreading movement, being transferred by the ears on the wings to the keel, allows free exit for the column of stamens and the pistil which were formerly wrapped within the keel in such a manner that the pollen could not readily reach the stigma Unless this spring mechanism be set off by insects, or other external forces, the flowers, with few exceptions, will wither without setting seed.

the flow is constant except that sometimes the first crop is a little light. Both of these districts report that the color of the last extraction of honey is perceptibly darker than earlier extractions. In the Sacramento Valley considerable honey of excellent quality is procured especially when either the second or third cutting of alfalfa is allowed to go to seed. Mr. Thos. J. Mumma of Dunnigan, states that alfalfa grown on light, sandy soil produces a pure white honey, while that grown on heavier soils is slightly amber in color."

Estimates by bee raisers in Arizona place the yield of honey by alfalfa at from 200 to 300 pounds an acre each year.

THE SEED CROP

The growing of alfalfa seed is an important industry in Arizona. The yearly income from this source alone to the farmers of the Salt and Colorado River Valleys has exceeded $250,000. Many of the lands of these valleys are well suited to this purpose. The dry, hot weather of May and June is favorable, also, and results in the setting of heavy seed crops. Four hundred pounds an acre is considered only fair, 500 to 650 pounds are not uncommon, and yields of 1000 pounds an acre are known. These seed crops usually ripen without a drop of rainfall on them from the time of blooming until threshed. This fact, with the comparative absence of dodder and other noxious weeds in the seed producing districts, renders Arizona grown alfalfa seed second to none in purity and quality.

Any soil on which alfalfa will thrive, may be made to produce good seed crops provided it has a sufficient slope to drain well. The best situations are such as have a light soil and a little too much fall for the best production of hay. Across these lands the water runs swiftly and it is possible to give the crop a light irrigation without soaking up the soil to such a degree as will over-stimulate the vegetative growth of the plants. For the best seed crops the stand should be thin so that each plant may secure an ample supply of light and make a stout, bushy growth.

Irrigation should be sparing. Where two irrigations are given for a hay crop, one is ample for the production of seed unless the plants begin to wilt, in which case they may be revived by a second light irrigation.

The general practice in Arizona is to save the second crop for seed. The first crop, having the benefit of the winter's rest and rains, together with one or more heavy irrigations, is usually very rank and succulent. Such a growth will produce an abundant and profitable crop of hay, but the seed yield will be low. The second crop is more uniform in its development and its blooming season falls in that time of the year when the weather is most favorable to the production of seed. In Arizona the second crop blooms in May, and the harvest occurs in June when there is very little danger of rain. Crops later than the second are not so well adapted to seed production, since they are liable to be hampered by summer rains and are more subject to the attacks of seed destroying insects.

The crop should be cut when from one-half to two-thirds of the seed pods have turned brown and before much shattering has taken place. When gathered too early the seeds, though in most

cases viable, have a greenish color and are shrunken. When fully matured they are plump, have a bright yellow color and bring the highest price on the market. American-grown seed often suffers in comparison with European or Asiatic alfalfa seed in this respect. In any case, alfalfa seed ripens unevenly. Some of the pods are yet green and immature while others are fully ripe and beginning to shatter. Good judgment is therefore required on the part of the grower to determine when to cut the crop in order to save the greatest quantity of well ripened seed.

In mowing the seed crop the machine should be furnished with an attachment for bunching or windrowing. This delivers the straw at one side and out of the way. If the machine and draft animals are allowed to pass over the fallen swath as the next is being cut much loss from shattering will result. Some farmers in the Middle West cut the alfalfa seed crop with a self-binder, but this machine is little used in Arizona. As soon as the alfalfa is cut it should be raked into windrows, or, if bunched, the bunches may be thrown together into small cocks. Many prefer to cure the straw in cocks assigning as a reason that the seed is prevented from bleaching so much, and that the straw is more protected from showers and cures better. Here it remains until it is ready to thresh or stack. Seed straw requires longer to cure than ordinary hay because of the comparative absence of leaves which assist in drawing the moisture from the stems. When thoroughly cured the seed may be threshed directly from the cock or windrow. If a thresher is not available at this time the straw must be stacked. It may be picked up from the windrow or cock either by hand or with a sweep-rake but in any case it should be handled as little as possible and with great care. When well cured the pods break off and are lost very readily. When, therefore, it is to be handled by hand and loaded on a wagon, it is customary to make the cocks small enough for a man to lift one at a forkful. This will avoid pulling the bunches apart in loading, with consequent shattering of seed.

It is also profitable to use a hay frame having a solid, close fitting bottom, or to spread a heavy canvas over the bottom of the frame to catch and save the shattered seeds. After the straw has been put into the stack, many growers claim that it should be threshed at once or else allowed to sweat before it is touched. If the stems are put up too green the stack will heat, thus destroying the bright color of the seed and frequently its vitality as well.

Large quantities of alfalfa seed are threshed with an ordinary grain separator having an alfalfa seed attachment. This frequently

consists merely in the readjustment of the concaves and the addition of two or three extra sieves. In sections where seed growing is made a business, a good alfalfa huller is indispensable. The reason for this is that the seed so obtained is much cleaner and there is less loss in the straw. In districts where both hullers and threshers are used, the owners of hullers frequently find it worth while to pay for the privilege of rethreshing straw that has been run through a grain separator.

Seed threshed by a separator or a huller without a recleaning attachment should be recleaned before being placed on the market. The shrinkage in weight due to recleaning, and the cost of the same, is more than compensated for in the increased price and in the satisfaction of handling first class seed. After being threshed the seed may be stored in sacks in a good dry, well aerated warehouse until ready for market. If the seed is damp it should be first spread out on a tight floor and shoveled over a few times until it is perfectly dry. If sacked and stored in a damp condition it will heat and lose in both color and vitality.

PROFITS IN SEED GROWING

Whether it is best to grow seed or hay depends upon the suitability of the soil for this purpose, market conditions and the relative prevailing prices of the two products. In districts located at some distance from a railroad market, the expense of hauling would be much less for seed than for hay.

The seed crop requires ten to twelve weeks for maturing. The comparative returns from seed and hay may therefore be figured on the basis that a seed crop will displace two cuttings of hay,

What may be considered a fait estimate of yields and profit per acre in alfalfa seed growing in the lower Gila Valley is given by Forbes[1] as follows:

COSTS

Two tons alfalfa hay sacrificed, at $6 per ton ,	$12 00
Water, three months supply	50
Cutting and hauling . ,	1 75
Threshing, 400 pounds of seed, at 3 cents	12 00
Sacking, at 15 cents per hundred pounds	60
Hauling, at 25 cents per hundred pounds	1 00
	$27 85

1. Forbes, R. H. Irrigation and Agricultural Practice in Arizona Ariz Agr. Exp. Sta., Bul. No 63 (1911), p 74.

RETURNS

One ton alfalfa straw		$ 4 00
400 lb seed, at 14 cents		56 00
		$60 00
	Costs ..	27 85
Net gain on fair average seed crop. .		$32 15

"In addition to the seed crop, two cuttings of hay and winter pasturage are obtained."

ALFALFA SEED FAILURES

According to the observations of the writer the most common causes of failure in the alfalfa seed crop in Arizona are three. These are as follows: Too thick stand, too rank growth and the attacks of insects.

Stand. In order to set a full seed crop the plant should be stocky, well branched and spreading. Light must have free access to the plant. Alfalfa never reaches this condition when crowded, but grows slender, with but few branches and only a small bunch of seed pods at the very tips of the stems. This is caused by the fact that the shaded part of a plant rarely branches; it produces but few flowers and even these very seldom set pods. The heaviest alfalfa seed crops are obtained where the stand 3$ light and open. The advantage gained in the production of seed by plenty of room is exhibited by the scattering plants at the edges of fields or along the rights of way of railroads. Such plants are often observed well loaded with seed pods when those in adjoining fields are setting seeds poorly. Light stands are, of course, open to the objections that the yield in hay is often lower and weeds are more apt to gain a foothold in the open spaces. Many farmers, however, overcome this difficulty to advantage by a thorough disking or harrowing in the fall and by the growing of winter grain in the alfalfa. This is cut for hay with the first crop of alfalfa, greatly increasing the yield and making a feed which is considered by many superior to alfalfa alone, especially for horses. The second crop is then left for seed. One or two fall crops of hay may then be secured in which the weeds are kept down by summer disking.

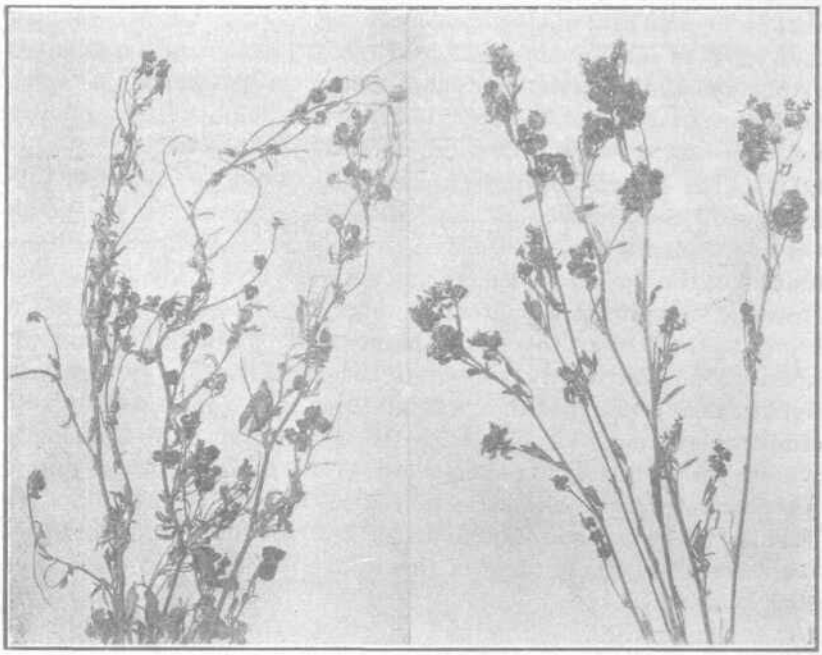
This same question of light and weeds, together with that of moisture conservation, has led to many experiments in row planting with interculture, for the production of alfalfa seed. This method

is proving highly satisfactory in parts of western Texas, Oklahoma, Utah and Kansas.

Rank growth: Any condition which promotes excessive vegetative growth of a plant also has a tendency to retard or inhibit the production of seed. This is especially true of rank growth, induced by an abundant water supply, and is even more marked when abundant moisture is accompanied by an excess of nitrogenous fertilizers or of humus in the soil. Alfalfa plants grown under such conditions will bloom freely but the flowers drop without setting pods. A very striking example of this came under the observation of the writer during the summer of 1911. In a plot of alfalfa growing in rows, a certain row was allowed to mature and go to seed. It happened that a leaking water tap was located at one end of this row. Water escaped just fast enough to keep one-half of the row moist. The remaining half received water only when irrigated. It was interesting to note that although the plants in the moist part of the row were from eight to ten inches taller than the remainder, practically no seed pods were set by them until after the water tap had been repaired; whereas on the drier part of the row a very abundant crop was produced. The soil was perfectly uniform and all the plants were cuttings from a single mother plant. The seed crop is best when just enough water is supplied to keep up a healthy but hard (not succulent) growth. Irrigation should be light and just frequent enough to prevent the plants from withering. Some fields are so level and

Fig. 9.—A full seed crop is set when the plant is stocky, well branched and spreading. Light must have free access to all parts.

the rate of flow across them so slow that water cannot be made to cover them without becoming too wet for a successful seed crop. Such lands are unfitted for seed production. It is for this reason that many farmers prefer "steep land", that is, land in which the slope is rather too much for the best hay crops. Across these fields the water runs swiftly, giving little time to soak in. The plants are therefore insured a light irrigation. The slope required for good seed production varies with the permeability of the soil. Sandy



A B

Fig. 10.—A.—On plants failing to set seed on account of an excess of moisture or too rank growth, the flowers drop soon after they bloom leaving the naked raceme attached. B.—When crowded the plants are slender, with but few branches and only a small bunch of seed at the tip of the stems.

land into which the water soaks readily must have more slope than stiff or clay soils. The more rank the growth of the plants, the thinner must be the stand if good seed production is to be secured.

Insects: Among the insects which attack alfalfa may be mentioned the alfalfa butterfly (*Eurymus*), thrips (*Asphondylia miki*), and the clover chalcis fly (*Bruchophagus funebris*). The butterfly is seldom a serious enemy to alfalfa seed crops in Arizona but the conspicuousness of the large yellow adults as they flit about the fields at flowering time has led many farmers to ascribe to them

damage which was caused by the presence of the chalcis fly or some other unfavorable circumstance. The larvae of the butterfly are green with either yellowish or pinkish stripes and they feed for the most part on the leaves. At times they may destroy a few flower clusters when they are young but serious damage from this cause is unknown to the writer.

Thrips, which may be observed as minute yellowish-brown and black creatures running over and among the flowers, are often present in great numbers. Since the mouth parts of these tiny insects are very feeble and fitted for scraping only, they can do but little damage individually. In the spring of 1911, thrips were very abundant on plants which the writer had selected as mother plants in certain breeding work. In the operation of artificially pollinizing these flowers the thrips were so thick that the operator's hands were covered by them. The flowers, moreover, exhibited plainly the effects of their feeding by the presence of many discolored patches on the petals. On many plants these discolored, scraped areas were so numerous that all of the flower clusters assumed a weak and sickly appearance. However, in spite of the great number of thrips and the apparent injury to the flowers, these same plants set an abundant crop of seed pods. That thrips may sometimes become numerous enough to so weaken the flowers that they will fail to set seed is indicated by numerous reports received by Dr. A. W. Morrill, State Entomologist. During the spring of 1911 there were several complaints of a more or less complete failure of the seed crop in the vicinity of Phoenix, due possibly to the ravages of millions of thrips everywhere present in the flowers. Definite proof of this injury is wanting in the opinion of Dr. Morrill.

In the months of June and July the writer has frequently observed peculiar straight or only slightly curved alfalfa pods. On examination such pods were always found to be without seeds. If taken in time they were often found to contain small reddish-orange larvae. On submitting specimens to a member of the Bureau of Entomology of the U. S. Department of Agriculture these were identified as the immature stage of *Asphondylia miki*. Over limited areas the writer has noted as high as 25 to 30 percent of the pods destroyed by this insect. Injury on a large scale has not, however, been observed up to the present time.

The chalcis fly (*Bruchophagus funebris*) is in all probability the worst enemy of alfalfa seed in Arizona. The damage is often the more serious for the reason that the adult insect is so small as to escape the notice of all except the most careful observers, and the damage is

hidden until the crop is threshed, then exhibiting itself only in the reduced yield.

The adult chalcis fly is a minute, black, wasp-like insect slightly less than one-twelfth of an inch long. The eggs are laid in the spring by females which have lived over from last season as larvae within seeds which had fallen to the ground from the previous crop, or which had remained on volunteer plants along the roadsides throughout the winter. The female alights on the calyx soon after the flower has bloomed and, thrusting her tube-like ovipositor (egg laying duct or tube) through the walls of the calyx and ovary (embryo pod), deposits her eggs in the ovule (embryo seed). The eggs may also be laid in the young pods after the petals have fallen away. As the ovule develops, this egg hatches and the resulting larva feeds upon the interior of the growing seed. By the time the seed is mature the larva is grown and ready to transform into the winged adult. It has by this time devoured all of the interior of the seed and has left only the hull. A small round hole is now egnawed through the hull and also the pod through which the fly escapes. During growth and development affected seeds and pods have much the same appearance as the healthy ones. It is not until the seeds are mature that the presence of the fly can be detected. Infested seeds are then brown and much lighter in weight than those which are sound and viable. Since all that is left of the destroyed seeds are the outer shells they are for the most part crushed in threshing or else blown out by the fan. The larvae of the chalcis fly are therefore not abundant in commercial seeds.

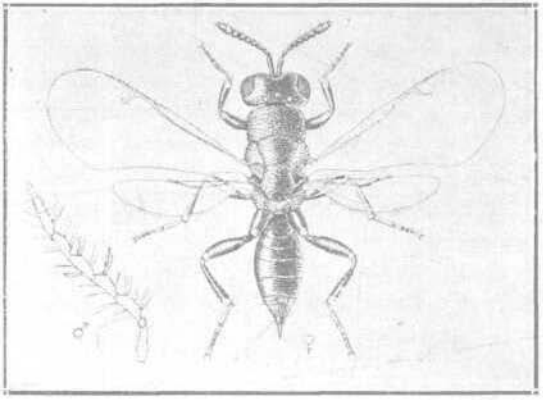


Fig. 11.—Alfalfa Seed Chalcis Fly. Adult female and antenna of male, the former enlarged about 18 times. (After Webster(

Adult flies maturing from eggs laid in the spring begin to appear in Arizona in early June and continue to emerge throughout July and August. They may then be observed flying about the plants in search of pods and flowers at the right stage for the deposition of

eggs. The shortest time of incubation (from egg to adult) must be approximately six weeks, since this is the usual time from flower to ripe seed. The larger number of the flies emerge at this time, but there are certain belated individuals which do not come out for weeks or even months. Seeds collected October 1 to December 10, in 1909, contained many live larvae the following April. That larvae, from eggs laid in April or May, might not emerge until the following spring, has not come under the observation of the writer,

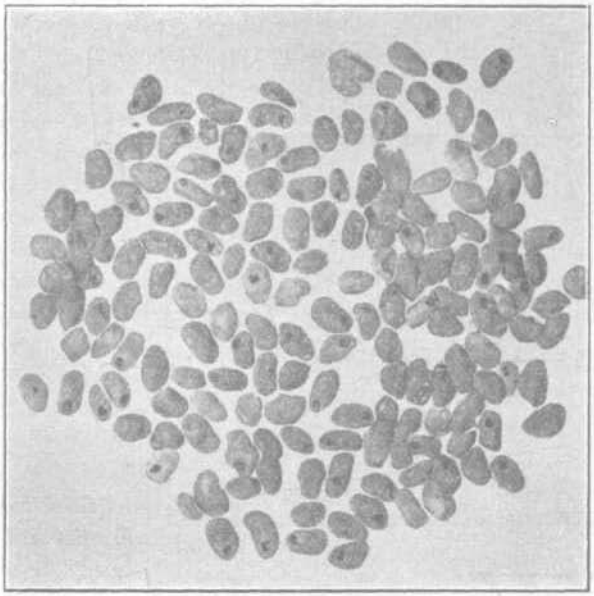


Fig. 12.—Alfalfa seed destroyed by chalcis flies. By the time the seed are mature the larvae of the chalcis flies are mature. They then escape by gnawing a small round hole through the seed-coat.

but Folsom of Illinois[1] found that June 21, adults issued from heads of red clover which were collected as late as June 5 of the following year. Since the first egg-laying period extends over more than a month in the spring, and since the time of incubation may vary from a little less than six weeks to nearly a year, there is no discernible interval between the appearance of the first and second or succeeding broods. However, each generation multiplies the number of insects. The percentage of injury, therefore, increases with the season. Fields where the loss from chalcis fly would not exceed 10 percent in the spring, will sometimes sustain a loss as high as 80 percent when a seed crop is attempted in the fall. As the season advances a smal-

1. Folsom, J. W. Insect Pests of Clover and Alfalfa. Ill. Agr. Exp. Sta. Bul. No. 134 (1909) p. 128, 129.

ler proportion of the larvae emerge at the expiration of the usual period of incubation (about six weeks or somewhat less), and a greater percentage of individuals does not emerge until the following spring.

The amount of damage done by the chalcis fly varies with the season. Alfalfa seed brought from Yuma in early June, 1910, showed 6 percent loss June 26, 1911, seeds from the same locality were infested to the extent of 50 percent.

At Phoenix during 1909, counts made at intervals from October 21 to December 10, indicated an average loss of 74 percent on a heavy crop of pods set. At Tucson, during June, 1911, the average damage amounted to 80 percent; in September of the same year the loss was 88 percent. Pods from Buckeye in June, 1911, showed a loss of 65 percent of the seeds. Material from Thatcher received July 8, 1911 was injured to the extent of 26 percent.

The loss seems to increase as the season advances until, in September and October, the destruction is usually nearly complete. A number of plants carefully hand-pollinated during August and September, 1912, had set a heavy crop of pods. When these pods matured in October practically every seed had been destroyed. Hundreds of pods were crushed without finding a single good seed. The crop of pods was therefore not worth harvesting, although much time and care had been devoted to its production.

The average loss calculated from the samples collected during 1911 was 61.7 percent, ranging from 26 to 88 percent in different samples. The writer believes this is much above the usual loss, since he is sure that chalcis flies were much more numerous at Tucson than on average years, and he met with much more complaint of more or less complete failures during that season than had been previously reported. If, however, we divide the present loss by three and assume an average of only 20 percent we still have in the chalcis fly an enemy of grave economic importance. It simply means that where we now harvest 400 pounds of seed to the acre we should harvest 500 pounds. At current prices for alfalfa seed this would mean $12 to $14 an acre and to a man with 40 acres in seed, a financial loss of $480. For the whole State it would mean a loss of more than $60,000 annually.

Since the adult insect does not feed upon the leaves of the plant, and since the eggs are deposited within the tissues of the developing seed pod where they are protected from all exterior disturbances, applications of poison sprays would probably be without effect. It has been suggested that some substance having a disagreeable odor might be sprayed on the flowers. This, being obnoxious to the in-

sects, would deter them from laying their eggs within the sprayed flowers. Such a substance is, however, unknown to the writer and even if such a spray could be found it might also drive away the bees and thereby prevent the fertilization of the flowers. It is the opinion of the writer that the most promising means of escaping the ravages of the chalcis fly lie in the production of the seed crop in early spring before the flies become sufficiently numerous to do great damage. It seems that only a small percentage of the flies live over winter. The first generation in the spring can, therefore, do but little harm. If, however, the seed crop is deferred until adults hatched from eggs laid in the early spring have matured, the infestation and damage will be many times multiplied. The writer would therefore advise the making of the seed crop as early as possible. It is the usual custom among Arizona seed growers to cut the first crop for hay and allow the second to mature seed. The reason for this is that the first crop is generally too rank in growth to set seed well. It may bloom readily but the flowers fall without producing pods. In late years, however, many farmers, especially in the vicinity of Yuma, are finding that the first crop can be so handled that it will set seed, and they have secured some remarkably heavy yields by this means. The greater tendency of the plants to make heavy vegetative growth in early spring after the winter resting period requires greater care in irrigation in order to hold in check the purely vegetative growth, and at the same time produce hardy and healthy, seed producing plants.

The production of alfalfa seed in old bermuda pastures has been profitably practiced on some farms. It has been found that by lightly disking the sod in pastures which have been over-run by bermuda, and sowing and harrowing in the alfalfa seed, a light stand of plants may be secured. Such a stand is especially favorable for the production of seed. The bermuda seed is easily removed by means of a sieve and fan, and the mat of grass keeps out other weeds but does not itself shade the alfalfa. Such a field should be especially favorable for controlling the water supply and securing early seed crops, largely escaping the chalcis fly.

Since the chalcis fly only lives over winter in the larval state within seeds shattered to the ground, and on plants which have escaped the mower, it would be advisable to destroy all such seeds by cutting and burning or turning under with the plow. If no seeds were allowed to be produced after July, or if all such as were produced after that date could be destroyed by December 15, we would be practically without chalcis fly injury the following year. Any meas-

tires, moreover, which have for their purpose the destruction of waste seed during the fall or winter will prevent loss from the chalcis fly the following year to such extent as they are successfully accomplished.

The chalcis fly also infests bur clover, which is very common in the alfalfa growing sections of Arizona. Since this blooms earlier in spring than alfalfa it serves as an excellent breeding ground for the first brood. Where bur clover is plentiful in early spring the infestation of the second crop of alfalfa by the chalcis fly is increased. The destruction of all bur clover in communities devoted to the growing of alfalfa seed would therefore be highly advisable.

ENEMIES OF ALFALFA

INSECTS AFFECTING THE ALFALFA HAY CROP

Insects which affect the seed crop have already been discussed. There remains to describe those whose damage is confined to the leaves, stems or roots.

The Alfalfa Caterpillar (*Eurymus eurytheme* Boisd): Aside from the chalcis fly, this is perhaps the most serious insect enemy at present known in Arizona. Usually the loss is not heavy but in some sections and in some years an entire crop may be destroyed by them. The irrigated sections of the Colorado Valley in the vicinity of Yuma, and the near-by Imperial Valley country of California, have so far reported the most regular appearance of this insect in damaging numbers. It is the caterpillar or worm stage of this species that does the harm and not the adult butterfly. The latter flitting over the fields in great numbers seem very formidable. Many farmers, therefore, ascribe to them damage to the seed crop which is caused by other insects or unfavorable circumstances. The fact is that these butterflies feed only on the nectar of the blooms and in no way injure them.

The following description of the adult larva is quoted from Wildermuth[1]: "The wings of the adults vary in color from yellow to white, being usually a sulphur-yellow above, with black outer margins, a conspicuous black spot in the center of each fore wing, and a faint yellowish spot in the center of each hind wing. The under side of the wings is of a lighter shade than the upper surface, and is the side noticed when the butterfly is at rest with its wings folded above its back. The wing expanse is nearly two inches, in some it is a little less than this and in a few a little more.

1. Wildermuth, V L The Alfalfa Caterpillar U S Dept of Agr Bur Eat. Cir No 133 (1911), p 0

"The full-grown larva is usually one inch long or sometimes a little over, dark green in color, with a white stripe on each side, partially broken by black and red dots at each spiracle. There is often an intermediate, narrower, and less distinct white line just above each of the lateral lines. In some specimens a black or dark green median or dorsal line is also present."

This pest is normally held in check by several parasitic insect and fungus enemies. Especially is this true of a certain fungus disease of the larva. This disease is favored by humidity and in other than an almost rainless country like the Imperial Valley of California, is ample to hold the butterflies in complete control.

There are several generations of this insect during one summer. The injury increases, therefore, as the season advances, until the greatest amount of damage is done in August and early September.

Concerning the control of this insect, Forbes[1] has suggested the following procedure

"The crop cannot be sprayed economically or safely with arsenicals. Close cutting of the alfalfa when the worms are most numerous in August will result in the death of great numbers, but enough will remain to eat down the new growth; and in cloudy weather an army of starving worms will migrate to the nearest green vegetation. For several reasons, worms among the number, our experience shows that it is good economy to withhold irrigating water for about thirty days, beginning August 15, resuming operations in September when the worm season is past. During this interval the alfalfa may be disked or renovated to good advantage. The advantages of this procedure are economy of water, destruction of worms by restricting growth of their food plant, and restraint of weeds by lack of water and by cultivation." In addition, Wildermuth suggests that since a generation of this insect requires approximately the same time as the growth of a cutting of alfalfa, the fields should be watched and whenever many worms are found, cut several days before the alfalfa blooms thus destroying the worms before they mature. By this means the infestation of the succeeding crop may be materially reduced.

The Green Alfalfa-Hopper (*Stictocephala festima* Say.): This insect is exceedingly abundant in the alfalfa fields of the Salt River Valley. In walking through a field in late summer or fall, perfect swarms of them fly with a quick motion and for a few feet only as the plants are disturbed. This insect is bright green in color, about

2. Forbes, R. H. The Intensive Cultivation of Alfalfa. Ariz. Exp. Sta. Hints for Farmers No. 93 (1912).

one-fourth of an inch in length with a triangular shape, being largest in front and tapering backward. The wings are transparent and membranous, the thorax is prolonged posteriorly almost to the end of the wings, ending in a fine point.

These insects suck the sap of the alfalfa and doubtless do more or less injury, but since excellent crops are raised in spite of them, very little endeavor is ever made toward their control.

Grasshoppers (Melanoplussp.): These occasionally become so numerous as to do considerable damage. The writer knows of one instance in the vicinity of Glendale, Arizona, during the summer of 1910, where a 40 acre field having an excellent stand was kept bare by grasshoppers for more than three weeks. On one corner of the field over which roamed a flock of some fifteen or twenty turkeys the alfalfa made a good recovery.

The best time to attack grasshoppers is in the egg stage. These are laid in the ground during early fall. Late fall or winter disking will turn out and destroy these to such an extent that damage by the adults the following year may not be feared. Of course this will not kill the eggs laid along ditches, fence rows or the neighbor's fields who do not practice fall disking. Attacks coming from these sources will have to be met by the keeping of turkeys, or in case they are severe, by the use of the hopperdozer. This consists of a shallow high-backed pan mounted upon runners sufficiently high that its bottom will scrape the tops of the alfalfa stubble. The pan is partially filled with water on the top of which floats enough kerosene to kill the hoppers which fall into it. These being disturbed, attempt to fly over the dozer but many of them striking the high back of the pan, drop into the oil and are destroyed.

The Harvester Ant (Pogonomyrmex sp.): The harvester ant is one of the most destructive insect pests of alfalfa in Arizona. The ants clear away all of the vegetation from a space surrounding the nest. These cleared areas vary in size according to the population of the colony. Such clearings 3 to 20 feet in diameter are very common, making up in some cases 5 to 15 percent of the entire area of the field, In certain sections of the Salt River Valley the average damage caused by ants amounts to at least 3 or 4 percent, Potassium cyanide dissolved in water is the most economical and efficient substance so far found for their destruction. One ounce of the dry cyanide should be used to a gallon of water. About one-half pint of this solution should be poured in and around the opening of each large nest. This will destroy all of the active members of the colony. The hatching of undestroyed eggs will

revive the colony in eight or ten days if it is left undisturbed. In order, therefore, to keep these ants down completely, or to destroy the nest entirely it will be necessary to follow up the first treatment with other applications at intervals of eight to ten days until no further living insects appear. A good grade of London purple is also highly recommended as a cheap and efficient means of destroying ants. This is applied in the powdered form at the rate of about half an ounce scattered in and around the openings of each nest. This poison acts more slowly than the cyanide.

Variegated Cutworm (*Peridromamargaritosa* Saucia.): An outbreak of the variegated cutworm in the Salt River and Buckeye Valleys was reported by Morrill[1] in the spring of 1911.

"In some cases the loss was equivalent to a cutting of hay." This insect is closely related to the army worms and is similarly subject to periodical outbreaks. These cutworms are dull brown or of a gray or greenish hue, generally marked with longitudinal stripes, oblique dashes, and dots, with head and following segment reddish-brown and horny. * * Examinations made in the Buckeye and Salt River Valleys soon after the first complaints were received showed that a parasite was actively bringing the cutworms into subjection. On May 10, 33 out of 50 specimens collected at random in various fields were found to be parasitized. * * It is probably safe to predict, that it will be several years before the variegated cutworm will again become noticeably abundant in the localities in Arizona where it was destructive in the spring of 1911."

Webworms, army worms and fall army worms which are some times very destructive in the Middle West[2] have not yet been reported in injurious numbers in Arizona.

The Alfalfa Weevil (*Phytonomus murinus* Fab.): This pest, though not yet known to be in Arizona, is likely to make its appearance at any time, since it is already scattered over several counties in a state adjoining on the north. Here the damage may amount to as much as 80 percent of the first crop which in that region means nearly half of the entire season's yield. In the vicinity of Salt Lake City, Utah, the estimated loss from this insect in 1910 was $140,000. Both the larvae and the adults feed upon the stems and leaves of the growing alfalfa. The young larvae destroy the buds while those that are older and the adults rasp the stems and leaves. The epidermis of the stalks is frequently eaten away entirely and the leaves are reduced to shreds. In severe attacks the

1. Morrill, A. W. Ariz. Hort. Com. 3rd Ann. Rept. (1911), p. 25.
2. See Kans. Agr. Exp. Sta. Bul. No. 155 (1908), p. 334, 335.

plants are completely defoliated. Considering the serious nature of this pest and the importance of preventing its entrance into the State, the following description is appended in the hopes that it may be recognized at sight.[1]

"The adults are oval in shape, from one-eighth to three-sixteenths of an inch long, and when freshly emerged from the pupa are pale brown with a distinctly darker line extending down the back, They are at first rather soft but, within a few days after emerging from the cocoon the wing cover and other parts of the body become hard and the color changes to a deep brown. There are some gray and black hairs mixed with these brown hairs so that it gives a spotted appearance. The beak is rather stout and slightly curved and about one-half as long again as the head. The males are somewhat narrower than the females and slightly smaller in size. As the summer progresses, some of the hairs and scales get rubbed off the weevil, causing it to appear darker in color, and before the following spring is passed many of them have so many scales rubbed off that they appear black with small irregular spots."

Concerning the alfalfa weevil and the danger of its introduction into Arizona, Dr. A. W. Morrill says that in addition to quarantine measures against the importation of household goods, livestock and hay from infested districts, Arizona should be further protected by inspection of alfalfa fields, especially those located near railroads and near cities and towns, so that the weevil, in case it is introduced by unpreventable means, may be discovered and the colony exterminated in its beginning.

DISEASES OF ALFALFA

Brown root rot: This is perhaps the most destructive alfalfa disease in Arizona. Its first evidence may appear in isolated dead or dying plants from which as centers the disease spreads in all directions. The affected areas, which may be from a few feet in diameter to several acres in extent, are generally more or less circular in outline and show very distinctly the encroachment of the disease upon the healthy plants. The spread of the disease during one season varies from 10 to 60 feet. The active zone is usually from 2 to 6 feet wide and shows on its outer margin plants just beginning to wither. Further in, the plants are dead and the leaves bleached to a straw color by the sun. On the inner rim of the zone the plants are blackened. In cases where they are dead, the fungus seems to

1. Titus, B. G, The Alfalfa Leaf-Weevil. Utah Agr. Exp, Sta. Bul. No 110 (1910),p. 63.

extend to the surface of the soil and complete the decay of the crown as well as of the roots. Where the plants are just beginning to wither, the diseased area usually extends to within 3 or 4 inches of the surface. Healthy plants just beyond the dying zone are found to have a few corroded or sunken spots on the roots and there is shown every degree of this affection until the roots are entirely diseased. They are then brown throughout and the fungus mycelium may be recognized as numerous fine brown threads distributed over the root surfaces.

Fig. 13.—Alfalfa root rot. The first stage exhibits sunken patches on the side of the taproot.

This brown root rot has been the cause of considerable damage on several farms in the Santa Cruz Valley near Tucson, and has been reported from two localities in the Salt River Valley. The extent of damage observed by the writer has varied from 5 percent to more than half the stand.

In Texas and Arizona neither trenching nor chemical treatment of the soil seems to have been efficient in holding this disease in check, but Shear and Miles state that a lack of soil aeration is a prominent factor in its development. They therefore highly recommend for the cotton root rot deep fall plowing, disking, and a two or three year rotation, as a means of controlling it. Contrary to the general idea that only alfalfa several years old will be attacked, one field in the vicinity of Phoenix was visited by the writer where alfalfa only nine months old was suffering rather serious injury from this disease. Several instances in which it had made its first appearance along irrigation ditches strongly suggest these as a means by which the root rot has been spread from farm to farm.

Leaf spot: This disease was first described by Libert, in France in 1832, but it is now found in all parts of the world where alfalfa is grown. It is more destructive in humid than in dry regions. In irrigated sections the first and second crops are more seriously attacked than later ones. In Arizona, the writer has seen only two instances in which it was the cause of marked injury, and this was upon rank growth just previous to the first cutting in early spring.

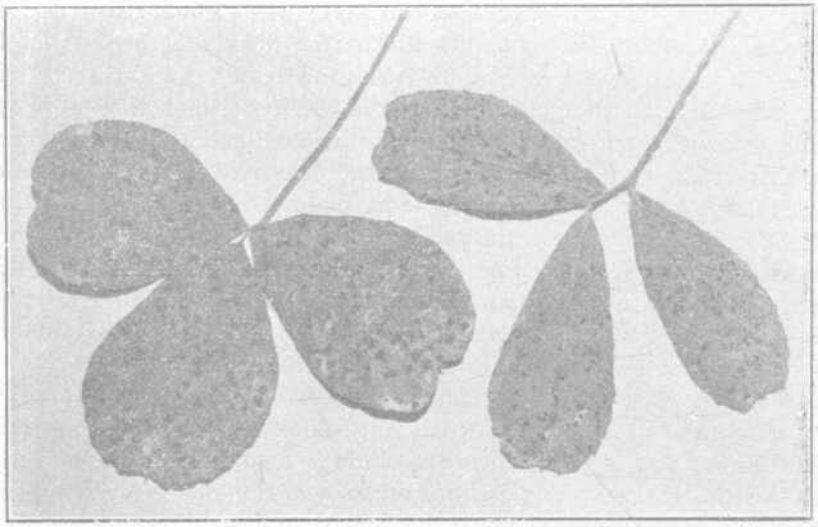
When the plants are about half grown, the leaf spot appears as yellowish-brown spots on the upper surface of the leaves. The affected area soon works through and appears on the under side of the leaf also. Badly affected leaves will turn yellow and drop off, thus reducing the forage value of the hay. The yield is also reduced through the loss of fallen leaves and by the weakening of the plant. The brown spots are caused by the growth of fungus threads or mycelia through the internal tissues of the leaf, which they destroy and cause to turn brown. Mats of fungus tissue are soon formed which produce small pustules near the center of the spot. These pustules consist of numerous sac-like bodies, each of which bears eight spores. Between the sac-like bodies may be seen non-spore-bearing threads which are called paraphyses. When the spores are ripe they are set free and blown about by the wind or scattered by dashing rains to the leaves of other plants which they soon infect.

The fungus causing this disease is technically known as *Pseudopeziza medicaginis* (Lib.) Sacc. The most practical treatment for it is frequent cutting. All of the hay should be removed from the field as early as possible in order that few shattered leaves may be left on the ground. By this means most of the spores are removed from the field, leaving the new shoots comparatively free from infection. Whenever this leaf spot becomes very damaging it is best to cut the alfalfa, whether it is ready or not, and allow the hay to remain on the ground long enough to become thoroughly dry, after which it should be burned over. Of course, by this means one crop is lost, but it will repay the loss in the increase of subsequent crops on account of the more effectual destruction of the fungus spores.

Rust (Uromyces striatus Schrot.): This disease has been noted by the writer on alfalfa in Arizona but once. During October, 1911, it appeared together with leaf spot on seedling plants in an alfalfa breeding plot on the University grounds. It was found on nearly all of the plants in varying degrees. Practically all of the leaves of those worst affected, and some of the stems also, showed the characteristic rust pustules. These plants were in a very unthrifty condition, fca>vi&g dropped most of their leaves, and such as were left turned to a pale yellow.

This disease causes round or elongated pustules on the undersides of the leaves. The epidermis is ruptured, disclosing a mass of reddish-brown spores. The rust pustule may be distinguished easily from the leaf spot by the fact that in the former the epidermis is plainly ruptured, whereas in the leaf spot this is not evident except in cross section and by use of the compound microscope. This disease has not heretofore proven sufficiently serious to warrant investigations concerning its control.

Downy mildew (*Peronospora trifolium* de Bary): This disease is at first made noticeable by the large irregular yellow or light colored



A B

Fig. 14.—A.—Alfalfa rust (*Uromyces striatus*). B.—Alfalfa leaf spot (*Pseudopeziza medicaginis*). Alfalfa rust may be distinguished from the leaf spot by its upturned open pustules. The leaf spot shows dark brown spots which are not upturned.

areas on the upper sides of the leaves. Upon examining the lower surface of the leaves it will be found covered by a downy gray felt. This felt consists of thousands of tiny branching grey threads or stalks which protrude through the stomata or breathing pores of the leaf from its interior, and it is upon these that the spores of the fungus are borne in grape-like clusters. These spores are carried by the wind to other leaves of alfalfa or clover on which they germinate and produce an internal mycelium. The fungus is carried over winter by means of resting spores, which are formed inside of the old leaves in late summer and autumn. In the early spring, when the new growth is especially tender, warm, foggy weather may so favor this disease that it may cause considerable damage. The

writer has found this mildew a number of times on alfalfa in Arizona but not as yet to such an extent as to do appreciable injury.

Crown gall: In the summer of 1909 the writer found, in a field near Phoenix, many alfalfa plants having large gall-like growths at the crown. Specimens of these were turned over to Dr. W. B. McCallum, then Pathologist of the Station, who identified the disease as alfalfa crown gall (*Urophlyctis alfalfae*).[1] It is also mentioned by Smith[2] as occurring in California.

These gall-like swellings undoubtedly check the growth of the plants although they are not killed outright. Should this disease become serious in a field, the land should be plowed and planted to some other crop until the gall fungus has been eliminated from the soil.

Phoma disease: Another disease first found by the writer and identified by Dr. McCallum (*loc. cit.*), is due to a species of *Phoma*, probably *herbarium*, which attacks the stems, usually just above the ground. The diseased areas are indicated by light colored sunken spots which often take the form of rings of diseased tissue around the stein. These rings are often made prominent by the growth of a callus girdle on the upper margin of the area. Such stems are either killed or seriously weakened.

Stem rot (Sclerotinia libertiana): This disease has not so far been noted in Arizona but it is said to be common in Southern California and is liable to appear in our fields. The following description is that given by Smith.[3] "The stems wilt and die after reaching nearly full size. Usually, scattering stems here and there about the field are affected and may be seen easily by their contrast with the thrifty green appearance of the other stalks. This trouble usually occurs most abundantly where there is a thick stand of alfalfa, heavily shading the ground, particularly in the spring when the ground is very moist. On pulling an affected stem it is found to be decayed at the base, and usually shows a more or less abundant white mold upon the surface if there is an abundance of moisture. In this mold small, roundish, black bodies develop which represent one stage of the fungus. It causes considerable damage to alfalfa at times in this State, and it has been reported as a serious disease in other states. The fungus is common, affecting various plants all over the world.

"No specific remedy can be suggested, but the disease usually disappears to a large extent during the summer and fall. Badly

1. McCallum, W B. Rept. Plant Pathologist in Ariz. Exp. Sta. Rept. 20 (1909), p. 583.
2. Smith, R. B and E. California Plant Diseases, Cal. Exp Sta Bul. No. 218 (1911), p. 1079.
3. & Smith, E. E. and E. California Plant Diseases. Cal. Agr. Exp. Sta. Bul No. 218 (1911) p. 1081.

affected fields should be plowed up and used for some other crop for several years."

Dodder (Cuscuta sp.): This is a parasitic vine belonging to the same botanical family as the morning glory. It may be recognized as a yellow thread-like vine without leaves, twining from plant to plant. These vines wrap tightly around the alfalfa stems and draw the nourishment from them. Allow the field to dry out for some time, cut the alfalfa close, remove it and leave the field dry for an additional two or three weeks. By this means the dodder may often be entirely killed without destroying the alfalfa roots. Badly affected fields should be plowed up and planted to a cultivated crop or oneor two years.

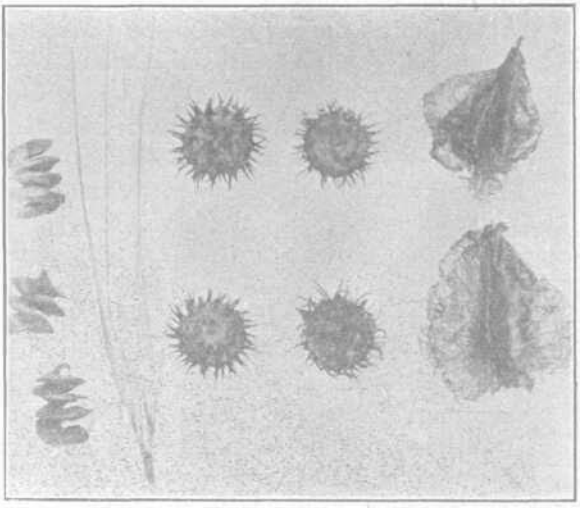


Fig. 15.—Pods of (a) Alfalfa, (b) Wall barley, (c) Bur clover, and (d) Canaigre.

WEEDS

Insufficient preparation of the land, cheap, poorly cleaned seed, lack of cultivation, neglect of ditch or canal banks and over-grazing, may be listed as the chief causes of weed infestation in the alfalfa fields of Arizona.

When heavy crops of mature weed stubble containing ripe seeds are turned under and incorporated with the soil during the preparation of the seed bed, we can only expect that these seeds will germinate and enter into immediate competition with the alfalfa. When young, alfalfa grows slowly, being easily overtopped and shaded by

the more rapidly growing weeds. It is undesirable to plant a field to alfalfa which is foul with weeds. Cultivated crops such as cotton, sugar beets or corn should first be grown until the soil is free from the live roots and seeds of all the more troublesome pests. Where it is impracticable to clear the land of weeds by growing cultivated crops, preliminary fallowing of foul lands should always be practiced before alfalfa is planted. This is best accomplished by turning the weeds under before their seeds are ripened. The land should then be irrigated. As soon as the new crop of weeds has well started it

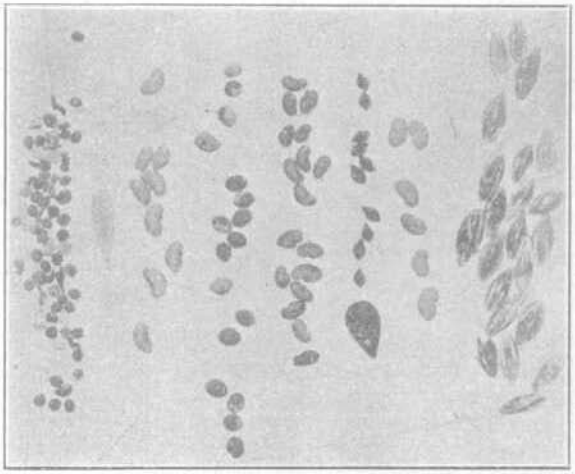


Fig. 16.—Seeds of (1) Dodder (*Cuscuta arvensis*), (2) Wall Barley (*Hordeum murinum*), (3) Spotted Clover (*Medicago maculata*), (4) Sour Clover (*Melilotus indica*), (5) Alfalfa (*Medicago sativa*), (6) Small seed above, Dock (*Rumex crispus*), large seed below, Canaigre (*Rumex hymenosepalus*), (7) Bur Clover (*Medicago hispida*), (8) Johnson Grass (*Sorghum halepense*).

may be destroyed with the disk and harrow. Exceptionally foul land may require a repetition of this treatment before all of the weed seeds which are lying dormant in the soil may be induced to germinate, and thus make possible their destruction. In the case of perennial weeds like dock, canaigre, Johnson and bermuda grass, the fallowing should be preceded by a summer of close grazing which has the effect of weakening the roots of these pests and causing them to be developed near the surface. The fallowing then should be dry in order to expose and destroy the persistent underground parts.

On poorly prepared, improperly leveled land a good stand of alfalfa is seldom obtained. Where the stand is thin all kinds of weeds easily gain an entrance to the field. On the other hand, when once a perfect stand is established it shades and occupies the ground

so completely that only the most vigorous of noxious weeds can secure a foothold at all and even these do so slowly.

Not less important than the preparation of the soil is the seed we put into it. No matter how completely we destroy the weeds previously present, if the same or perhaps worse pests be again introduced with the seed planted we shall have foul and unproductive fields.

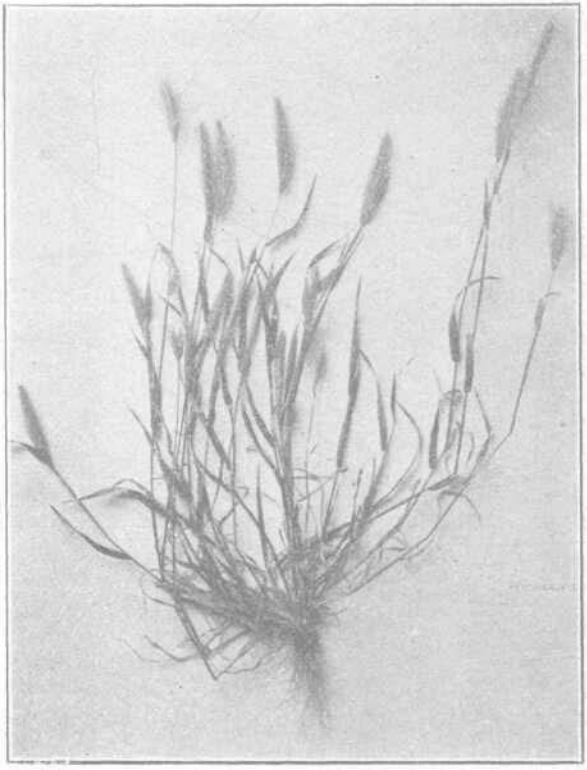


Fig. 17.—Wall barley (*Hordeum murinum*).

In Arizona the planter should be especially watchful against dodder (*Cuscuta sp.*), dock, and canaigre (*Rumex sp.*), wall barley (*Hordeum murinum*) and Johnson grass (*Sorghum halepense*). Alfalfa seed containing any of the above weed seeds should be refused, since a field once contaminated is hard to rid of their presence. The seeds of dodder are smaller than those of alfalfa and are round, lacking the characteristic bean shape of the latter. Their seed coats also present a rough and pitted appearance. Wall barley is a grass and

its threshed seeds are about four times the length of an alfalfa seed and a little broader. Dock seeds are three cornered like buckwheat, dark reddish-brown and about the same size as alfalfa seed. Canaigre seeds are of the same color and shape as dock seeds, but they are several times as large, being about three times as long as alfalfa seeds. The seeds of Johnson grass are spindle shaped and dark brownish red to nearly black. They are about three times the length of an alfalfa seed. A comparison of the general appearance, shape, and size of these weed seeds with those of alfalfa may be made by consulting figs. 15 and 16. These figures also show the seeds of sour clover and the two most common bur clovers occurring in the alfalfa fields of Arizona. The seeds of sour clover are usually more greenish than those of alfalfa. They are rougher, more plump and round, and have the eye (hilum) nearer to one end than do alfalfa seeds In some of these characters they resemble dodder seeds but they are somewhat larger, have a more conspicuous eye and are more elongated than the nearly round dodder seeds. The seeds of the two bur clovers very much resemble those of alfalfa, but they are larger and flatter and generally have a lighter color. These three clovers are present in a great many alfalfa fields in Arizona and while the forage they yield is nutritious and they are not bad weeds, lack of productiveness and the fact that they are annuals render them much less valuable than true alfalfa. Moreover, the spaces which they occupy in spring are left vacant during midsummer and fall, and permit the ingress and establishment of all sorts of weeds. For these reasons alfalfa seed which contains any considerable admixture of sour or bur clover seeds should be rejected. Before buying alfalfa seed it is always best to request samples, which should be inspected carefully, and if any appreciable quantity of weed seeds is present, or if any of the especially noxious ones are observed, the purchase should not be made. In case of doubt it is always best to send a small sample (about two ounces) to the Experiment Station for examination by an expert. Alfalfa seeds of low germination strength are likely to give a poor stand and thus allow the ingress of weeds.

Shallow rooted annual plants like water grass, pigweed, wild oats, wall barley, sour and bur clover, and to a certain extent, also, bermuda grass, may be controlled by cultivation. Neglect of summer cultivation often results in over-running with weeds fields which otherwise should yield a good quality of hay throughout the season.

Foul ditch and canal banks constitute a perennial source of infestation by all sorts of weed pests. Especially is this true of Johnson and bermuda grasses since the seeds of these two plants float readily.

Infestation of this sort is most liable to occur near the heads of the lands as the seeds floating in from the ditches usually lodge among the stubble before they have gone far into the field. When the land is originally free from bad weeds, it is practicable to control this source of infestation by going over the fields two or three times during the summer and cutting out with a sharp shovel every sprig of weed pests as soon as they appear. Where the water was badly infested with bermuda grass seed, such a method of summer patrol with a shovel has cost on a certain farm at Yuma about $3.50 an acre per year including the cleaning of the field laterals. The increased yield of alfalfa has several times repaid this extra expense. It is, of course, better to eliminate this source of weed seed by keeping the ditch and canal banks clean. Where these are badly infested with bermuda and Johnson grasses, it has been found practicable to prevent the production of seeds by close grazing with sheep.[1] This grazing also weakens the rootstocks of these plants to such an extent that they are subsequently much less difficult to destroy with the plow or shovel.

In many sections of Arizona the alfalfa fields are habitually overgrazed. By this means much of the stand is killed and the remaining plants are weakened to such an extent that they are easily overcome by weeds. Excessively grazed fields are especially liable to be over-run by bermuda grass, since the tough stems and prostrate habit of this plant enable it to endure without injury such close grazing as would completely destroy alfalfa. In the spaces left by over-grazing, annual weeds and grasses obtain a foothold and soon further reduce profits from the alfalfa by cutting down both the yield and quality of the hay produced.

THE WORST WEEDS AND THEIR CONTROL

Johnson grass (Sorghum halepense): This is a coarse, smooth, upright grass which grows in clumps. It seeds at from 2 to 6 feet in height according to the season, soil and moisture. The heads form loose spreading panicles and the seeds are dark reddish-brown when ripe. The plant is perennial from large, jointed, underground rootstocks. Such a stem coming to the surface develops for itself an independent crown, which in turn sends up many stems and gives rise to a new bunch of grass. From this clump as a center, new underground stems are put forth in all directions. In this manner not only is the grass continuously spread, but it also fills the soil with the

1. See Ariz Exp Sta Timely Hints for Farmers No 103, 1914.

thick and resistant rootstocks, rendering the complete eradication of the pest exceedingly difficult. The reason for this is fully realized when one learns that every joint of a rootstock which may be broken apart by the plow or harrow is capable of sprouting at once, or else lying dormant in the soil for several months until favorable conditions arrive, and then putting forth roots and branches. Unless, therefore, it has been exposed on the surface and thoroughly dried out, each piece acts as a cutting to further scatter and increase the infestation. New rhizomes are being formed at all times when the grass is in active growth. There is, therefore, no season of the year when it may be safely neglected.

Johnson grass seeds are smooth and shining on the back, slightly flattened, and spindle-shaped with a narrow apex. They are about three times as long as an alfalfa seed. The seeds of Johnson grass are readily scattered about in barnyard manure, in the droppings of stock fed on infested hay and by means of water from irrigation ditches. This latter is probably the most prevalent means of their dispersal. On the side of a canal furnishing water to one of the richest alfalfa districts in the State, the writer observed a number of large bunches of Johnson grass with ripe seeds; and Salt River from Roosevelt Dam to Granite Reef is bordered with numerous patches of it.

The first step in preventing the spread of Johnson grass is to keep the canal and ditch banks scrupulously clean. The second step is to inspect the fields carefully, at least two or three times a year, and dig out, root and branch, every sprig of Johnson grass found. If the land is not already infested the cost of this bi-annual or tri-annual inspection will be insignificant. In some cases, however, the infestation is already beyond control by hand digging. In such fields there is no hope of saving or restoring the stand of alfalfa. They should be mown frequently and care exercised not to allow any of the Johnson grass to go to seed. With these precautions, however, the land may remain in alfalfa until the stand becomes too poor to yield profitable crops. The writer would advise, also, that all cultivation of such fields be withheld and that they be grazed closely during the early fall. When the hay crop from a Johnson grass infested field becomes unprofitable it is well to pasture it closely for an entire summer before plowing the field in the fall. Poor aeration and starvation, due to close summer grazing, will therefore weaken the root systems of both alfalfa and Johnson grass and cause them to be developed near the surface, thus facilitating their destruction. When the ground has been grazed clean by stock and is rather dry,

preferably in the early fall after the summer rains, it should be plowed to a depth of 5 or 6 inches and left loose and cloddy. This will insure deep and thorough drying. Water is withheld and the ground stirred with the disk at intervals throughout the winter. At the beginning of the spring season it should be plowed again,—10 or 12 inches deep if possible. This is followed by the disk or weeder at intervals to keep down all surface growth until the planting season for cotton or corn. All plowing should be with a mould-board plow. The disk plow is not satisfactory in that it does not cut off the more deeply lying roots. The cultivated crop should be kept perfectly clean by the frequent use of the plow and hoe throughout the remainder of the summer. The land may be planted to sugar beets the following fall or to other hoed crops in the early spring. After two or three years of cultivated crops in which not a sprig of Johnson grass is allowed to grow, the field is again ready to be planted to alfalfa. The estimated cost of the procedure, as here outlined, previous to the planting of the summer crop, would be about $5 to $10 an acre.

Bermuda grass (Cynodendactylon): This is a low creeping grass with long, wiry stems and fine, soft leaves. The seed stems are upright, from 3 to 6 inches long, bearing at the summit four to several finger-like spikes. In addition to bearing seeds it spreads by means of long, trailing stems which take root at the joints. It also produces underground rootstocks, which, coming to the surface, establish new bunches of grass. The rootstocks of bermuda grass never penetrate so deeply as those of Johnson grass. It is therefore much easier to eradicate. A bermuda sod can be destroyed by turning, with a mould-board plow, about 4 inches deep in early May when the ground is fairly dry. This should be followed by one or two diskings so as to expose and thoroughly dry out the loosened soil layer. Water should be withheld and about the 15th of June it should be plowed again about 8 inches deep. One or two additional diskings before the rainy season sets in should be sufficient to destroy the grass.

Wall barley (Hordeummurinum): This is an annual grass which first appears in March and April. It grows in tttfts from 6 to 15 inches high. The seed spikes are dense and bear long stiff beards, somewhat resembling a small barley head. They ripen during April and May. This grass does little harm by crowding the alfalfa since it only occupies spaces where the stand has died out from other causes. Its chief injury results from the presence of its stiff beards in the hay of the first and second cuttings. The beards often lodge in the throats of animals that eat the hay, with serious results.

Alfalfa hay containing any considerable quantity of wall barley therefore brings a lower price than that which is free from it. The best way to control wall barley is to maintain a perfect stand of alfalfa.

Water grasses (Echinochloa colona, Leptochloa imbricata, Eriochloa sp. and *Paspalum sp.):* Several species of grasses are known collectively as water grasses. They usually make their appearance

Fig. 18.—Sour clover (*Melilotus indica*)

after the beginning of the rainy season, especially in low places where the alfalfa is thinned out by over-irrigation and where there is a little excess of alkali. They are also found in the irrigation ditches and around the borders of small reservoirs and settling tanks. Jungle rice (*Echinochloa colona*) is probably the most common of these grasses in the Salt River Valley. It is easily dis-

tinguished by transverse zebra-like markings of purple on the leaves, None of these grasses should be classed as noxious weed pests. They simply occupy space left vacant by the dying out of the alfalfa. They may be controlled by summer cultivation and by the maintenance of a good stand of alfalfa.

Dock and Canaigre (Rumex crispus, hymenosepalus, etc.). The docks occur in clumps and may be recognized by their rosettes of elongated, more or less crinkled leaves in early summer and their crowded panicles of triangular seeds in late summer and fall. The roots are fleshy and perennial. The docks have a single taproot whereas the roots of canaigre branch and resemble those of the dahlia or sweet potato. These weeds are easily controlled by digging out with a mattock when present in limited quantity, or by one or two deep plowings when very abundant.

Pigweed (Amaranthuspalmeri): This weed is of frequent occurrence in alfalfa fields where the stand is thin. It produces an upright stalk if unmolested, but if cut off near the base will form a bunch of ascending stems. The leaves are elongated, narrowing gradually toward the base, and with a pointed apex. They occur alternately on the stem. At the juncture of stem and leafstalk there occur two small stipules which commonly harden into a sharp prickle or thorn. The clusters of small flowers, produced in the axils of the leaves, are also protected by sharp prickles. These, however, do not harden until the plant is mature. If cut green, therefore, pigweed makes a fair quality of hay. Pigweeds are usually most troublesome in the alfalfa after the beginning of the rainy season. The control of this is the same as for other annuals—that is, summer cultivation and the maintenance of a good stand of alfalfa.

Sour clover (Melilotusindica: The young plants of sour clover look very much like those of alfalfa, but when they come to maturity are easily distinguished by the upright racemes of yellow flowers. The pods are also smaller and not coiled into a spiral as they are in alfalfa. Sour clover is conspicuous only in early spring. It makes a fair quality of hay and would not be objectionable were it not that it is an annual and dies out during the heat of the summer. The space occupied by it Is therefore left vacant for the ingress of other less desirable weeds. Where the stand of alfalfa becomes too poor through the encroachment of sour clover, it should be plowed up in March or April before the seeds of the sour clover have ripened. A subsequent irrigation to induce belated seeds in the soil to germinate, followed by one or two diskings and the cultivation of a summer crop, should get rid of this weed. In reseeding the land to alfalfa,

care should be exercised to plant only seed which is free from all impurities. It is through the seed planted that infestation of alfalfa fields with sour and bur clovers usually originates.

Bur clover (Medicago hispida): Although this belongs to the same botanical genus as alfalfa, it may be easily distinguished from it by the yellow flowers and spiny pods. The hay produced by it is of good quality, but the plant is small and prostrate and not nearly so productive. It is, moreover, an annual and therefore open to the same objections as mentioned for sour clover. The most serious

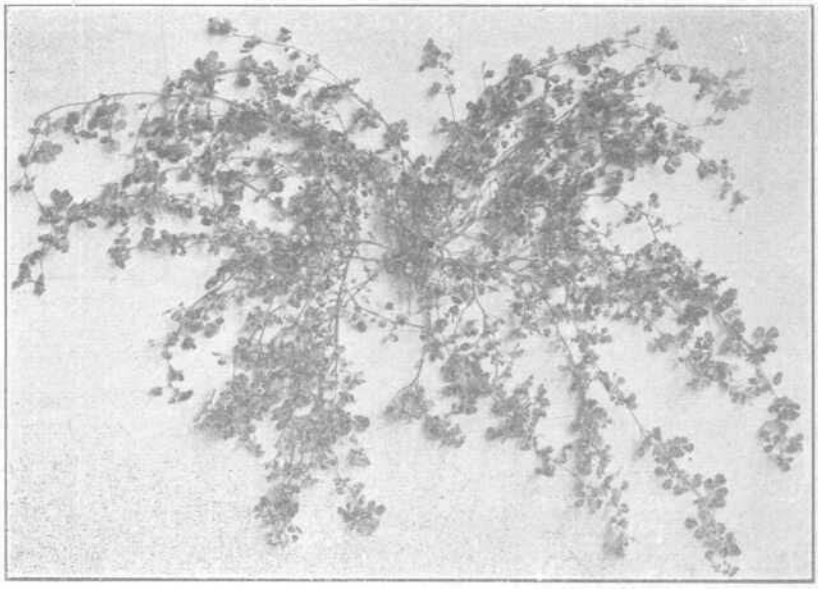


Fig. 19.—Bur clover (*Medicago hispida*).

injury from bur clover, however, lies in the fact that it harbors the chalcis fly and offers early flowers in which a first brood of this insect is reared. By the time the alfalfa comes into bloom the chalcis flies are therefore much more plentiful and injurious than they would have been if only those individuals which lived over winter were present to infest the seed crop (See p. 298). The eradication of bur clover in sections devoted to seed raising is therefore highly desirable. The control of bur clover is the same as given for sour clover above.

REFERENCE TABLES

COMPOSITION OF ALFALFA

	PERCENTAGE COMPOSITION					Pounds per ton of air-dry hay
	Green	Air-dry (1)	Water-free (2)	Ensilage, fresh (3)	Ensilage, water-free (3)	
Water	75.00	6.86	. .	74 63	.. ..	137.2
Ash	2.96	10.65	8 06	2.89	11.41	203.0
Fat	0 41	1.54	2.42	2 48	9.79	31.8
Protein	4.03	15.00	14 25	3 60	14.17	300.0
Crude fiber	8.94	33.29	28.57	10.93	43.11	675.8
Carbohydrates	8.62	32.12	42.17	5.47	21.52	642.4
Total nitrogen	0.65	2.40	2.28	0.58	2.26	48.0

1. Headden, W. P., Col. Agr. Exp. Sta. Bul. 110 (1906).
2. Catlin, C. N., unpublished records, Chemical Dept., Ariz. Agr. Exp. Sta.
3. Dinsmore S. P., Nev. Agr. Exp. Sta. Bul. 72 (1909).

COMPOSITION OF DIFFERENT PARTS(1)

Second cutting, plants in medium bloom, twenty-eight inches high	PERCENTAGE COMPOSITION			
	Whole plant	Leaves	Stems	Flowers
Proportion of whole plant, green	100.00	43.37	49 55	7.08
Proportion of whole plant, dry	100.00	42.36	50 79	6.85
Moisture in green substance	79.20	60 37	58 41	60.77
Dry matter in green substance	20 80	39.63	41.59	39.23
Ash in water-free substance	10.20	13.45	7 69	9.00
Fat in water-free substance	2.53	4.50	0.99	2.02
Crude protein in water-free substance	16.86	25 27	8 26	28.64
Albuminoids in water-free substance	14.26	19.81	8.16	25.00
Crude fiber in water-free substance	33.49	13.16	52 86	15.04
Carbohydrates (starch etc.) in water-free substance	37.03	43.62	30.35	45.29

1. From Widtsoe, J. A., Alfalfa, Chemical Life History, Utah Agr. Exp. Sta. Bul. No 48 (1897)

DRY MATTER AND DIGESTIBLE FOOD INGREDIENTS OF ALFALFA COMPARED WITH THAT OF OTHER STOCK FOODS(1)

	PERCENT DIGESTIBLE FOOD INGREDIENT						
	Green alfalfa	Air-dry alfalfa hay	Wheat bran	Green timothy	Air-dry timothy hay	Green corn forage, whole plant	Air-dry corn forage, whole plant
Dry matter	28.2	91.6	88.5	38.4	86.8	20.7	57.8
Protein	3.89	10.58	12.01	2.28	2.89	1.10	2.48
Carbohydrates	11.20	37.33	41.23	23.71	43.72	12.08	33.38
Fat	0.41	1.38	2.87	0.77	1.43	0.37	1.15
Fuel value Calories pr. 100 lbs...	29,798	94,936	111,138	51,591	92,729	26,076	71,554

1 U. S. Dept. Agr. Year Book, 1896, p. 608.

FERTILIZING CONSTITUENTS IN ALFALFA AND STUBBLE

	Water, per cent	Ash, per cent	Per cent nitrogen	Per cent phosphoric acid	Per cent potash	Pounds nitrogen per ton	Pounds phosphoric acid per ton	Pounds potash per ton	Pounds per acre air-dry	Pounds nitrogen per acre	Pounds phosphoric acid per acre	Pounds potash per acre
Green hay[1]	75.30	2.25	0.72	0.13	0.56	14.4	2.6	11.2	...	...	..	...
Air dry hay[1]	6.55	7.07	2.19	0.51	1.68	43.8	10.2	33.6	...	...	..	...
Air dry[2] stubble and 6 in. of roots	...	4.24	1.82	0.42	0.78	36.4	8.4	15.6	5721	104.1	24.0	44.6
Roots below 6 in.[2]	...	..	0.75	0.22	0.71	15.0	4.4	14.2	10380	77.1	22.6	73.0
Total stubble and roots air dry[2]	...	..	..	..	..	..	..	..	16001	181.2	46.6	117.6

1. U. S. Dept. Agr. Year Book 1896 p. 611.
2. Compiled from Headden, W. P. Alfalfa. Col Agr. Exp. Sta. Bul. No. 35 (1896) p. 58-60

The stubble and root determinations were made on a good vigorous stand of alfalfa five years old. Alfalfa obtains its supply of nitrogen largely from the air. All other constituents must come from the soil. This crop therefore benefits the soil in adding humus and nitrogen to it but depletes it in phosphoric acid, potash and the other mineral constituents.

GRADES OF ALFALFA HAY ESTABLISHED BY THE NATIONAL HAY ASSOCIATION

Choice Alfalfa Shall be reasonably fine, leafy alfalfa of bright green color, properly cured, sound, sweet and well baled.

No. 1 Alfalfa: Shall be coarse alfalfa of natural color, or reasonably fine, leafy alfalfa of good color, and may contain 5 percent of foreign grasses, must be well baled, sound and sweet.

No. 2 Alfalfa: Shall include alfalfa somewhat bleached, but of fair color, reasonably leafy, not more than one-eighth foreign grasses, sound and well baled.

No. S Alfalfa: Shall include bleached alfalfa, or alfalfa mixed with not to exceed one-fourth foreign grasses, but when mixed must be of fair color, sound and well baled

No Grade Alfalfa: Shall include all alfalfa not good enough for other grades, caked, musty, greasy or threshed.