Experiment Station
of the
Kansas State Agricultural College
MANHATTAN.

Bulletin No. 133—February, 1906.

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Alfalfa Seed: Its Adulterants, Substitutes and Impurities, and their Detection.

No forage crop in the West is of as great and steadily growing importance to the agricultural interests as *Medicago sativa,* known in Europe as lucerne, and in America as alfalfa. The immense value of the alfalfa acreage to Kansas, and the high price of the seed, make it imperative that every precaution be taken to insure the purity of the commercial seed, and that every assistance possible in this regard be rendered to the farmers of the State and to the seed merchants doing business in the West. Especially has this necessity been rendered evident within the last two years. Within this period, there has come to the attention of the Botanical Department of the Experiment Station, the fact of the presence, in numerous cases and sometimes in considerable quantities, of adulterants, substitutes and impurities which, from the close resemblance of the spurious seeds to those of alfalfa, render them indistinguishable from the latter, to the eye of any average buyer. This introduction of spurious seed has, as a matter of fact, in some striking instances, gone so far as to amount to the total and complete substitution of a different species. The chief purpose and intent of this bulletin is to make as clear as possible the differences which exist to distinguish alfalfa seed from its most frequently used adulterants and substitutes.

The plant alfalfa belongs to the large botanical genus, *Medicago,* numbering some fifty species of annual or perennial herbaceous or occasionally woody plants which grow over central and southern Europe, and especially abundantly in the Mediterranean lit-

toral, as also in Central and Farther Asia, and the Cape of Good Hope region. Of all these species, but four or five are of economic interest or value. Beside alfalfa itself, which is perennial, there are three annual species that have been introduced into America — *Medicago lupulina* (Yellow Trefoil, Hop Clover or Hop Medic), *Medicago denticulata* (Bur Clover or Toothed Medic), and *Medicago Arabica,* also called Bur, Heart or Spotted Clover or Spotted Medic. All of these three species have some local and restricted forage value, and in places they are cultivated as forage plants; but the fact that they are not perennial plants renders them at once and for this reason inferior to *Medicago sativa.*

The Botanical Department of the Experiment Station has had its attention called to a number of cases in which seed of *Medicago lupulina* and *Medicago denticulata* have been substituted absolutely and entirely for and sold as alfalfa seed. *Medicago Arabica,* and other *Medicago* species, have not yet come to our attention as adulterants. It is the purpose of the writers to render as clear as possible the chief botanical characters distinguishing these plants from one another and from alfalfa.

Before considering the part that allied species of *Medicago* play in the matter of the adulteration of alfalfa seed, it will be interesting to discuss the characters of another closely related plant, belonging to a different genus, the seeds of which have been constantly found occurring in western-grown alfalfa seed, although usually not in sufficient quantities to be suspected as a conscious adulterant, namely, the seed of sweet clover, *Melilotus alba.*

An admixture of *Melilotus* seed in the seed of alfalfa is extremely difficult of detection to any but an expert, although, when the chief distinguishing differences are made sufficiently evident, as it is hoped will be effected through the accompanying photographs and drawings, an attentive buyer, with the aid of a hand lens magnifying 20 diameters, should be able to determine the facts for himself with considerable accuracy. Without the assistance of such a lens, however, detection will be practically impossible. So far as the plants themselves are concerned, *Melilotus* can easily be distinguished from *Medicago,* or alfalfa. While alfalfa plants rarely exceed 1½ to 2 feet in height, sweet clover ranges from 3 to 6 feet or more. The flowers of alfalfa are borne in dense, shortened spikes or racemes, compacted into a rather close cluster or head, and which, in the case of alfalfa itself, are purple in color, although in the other closely related species of *Medicago* discussed in this Bulletin they are yellow, resembling in this respect the flowers of *Melilotus officinalis* the yellow sweet clover, which is generally less

abundant than the white species through the western states. The flowers of the white sweet-clover, unlike those of alfalfa, are borne along slender stalks — "racemes" — which are from one to five inches in length, and on which the small, white flowers grow in open order, quite differently from the compacted clustered habit of the alfalfa flower-heads. The leaves of sweet clover are divided into three leaflets, as with alfalfa, but the botanical distinctions in this respect are scarcely worth dwelling upon, since the difference in the size of the plants, together with the color and habit of growth of the flowers, are sufficiently distinctive. Sweet clover is a biennial plant, while alfalfa is perennial. When, moreover, the pods of sweet clover (Plate VI1 Figs. 1 and 2) are compared with, those of alfalfa (Plate V Fig. 1 and Plate VIII Fig. 1) the differences are seen to be most striking. The two plants both bear their seeds in pods, a character common to the *Papilionaceoe* or Legume family, to which they belong in common. The pod of *Melilotus* is straight, and of a rather rounded oval outline, black when ripe, covered with rather coarse reticulations, and containing but a single seed. The pod of *Medicago sativa* is coiled in usually two or three turns, also black, and containing several, commonly about five seeds. The seeds of alfalfa and sweet clover, as was stated, appear on first notice to be almost indistinguishable. A close and accurate study, however, reveals very marked and striking differences that escape the unpracticed eye.

The seed of sweet clover, seen in bulk samples, is yellowish, while that of alfalfa has a greenish cast. This is a character, however, that would escape observation in adulterated mixtures, unless the amount of sweet clover seed added were quite considerable. The seed coat of alfalfa, as seen under the microscope, is smooth or covered with very fine dottings, while that of *Melilotus* has quite evident swellings, or protuberances resembling delicate papillæ, over the surface, giving it a somewhat "warty" appearance under the microscope. This difference, while evident in a comparison of Plates X and XIV, is still more strikingly set forth in the higher magnification shown in Plates XV and XVIII Pig. 2. It is noticeable, also, that the "veins," or vascular bundles that run out over the seed coat from the point of attachment to the pod, are distinctly bluish in the case of sweet clover, but colorless in alfalfa. In respect to size, the seeds of alfalfa will average slightly larger than those of sweet clover. The value of this distinction disappears, however, from the fact that in possible range of size, the two overlap. (See table.)

SIZE OF SEEDS OF ALFALFA AS COMPARED WITH THAT OF THE SEEDS OF ITS CHIEF ADULTERANTS.

SEED.	AVERAGE.	LARGE.	SMALL.	No. seeds measured
Medicago sativa	1.48 × 2.40 mm. .0582 × .0944 in.	1.66 × 2.93 mm. .0653 × .1153 in.	1.26 × 1.91 mm. .0496 × .0751 in.	100
Melilotus alba	1.50 × 2.12 mm. .0590 × .0834 in.	1.70 × 2.38 mm. .0669 × .0937 in.	1.28 × 1.72 mm. .0503 × .0677 in.	100
Medicago lupulina	1.46 × 2.03 mm. .0574 × .0799 in.	1.60 × 2.28 mm. .0629 × .0897 in.	1.30 × 1.74 mm. .0511 × .0291 in.	100
Medicago denticulata	1.79 × 3.02 mm. .0804 × .1188 in.	1.92 × 3.87 mm. .0655 × .1523 in.	1.60 × 2.59 mm. .0629 × .1011 in.	25
Medicago arabica	1.53 × 2.75 mm. .0602 × .1082 in.	1.73 × 3.11 mm. .0681 × .1224 in.	1.34 × 2.46 mm. .0527 × .0968 in.	25

Practically, the form of the seeds remains as the chief determinative factor. In general, the seeds of sweet clover are fuller, plumper, and rounder than those of alfalfa (see Plate XXI, and compare Plates X and XIV), and while many cases of a distinctly bean or kidney-shaped seed occur with alfalfa, as illustrated in the three seeds photographed in Plate XV, no such cases will ever be found among the seeds of *Melilotus*. It is sufficiently evident from the comparison of Plates XV and XVIII, Fig. 2, that were all alfalfa and sweet clover seeds of the types here shown, respectively, no difficulty would ever be experienced in distinguishing them. The test comes in the distinguishing of apparently intergrading types. Examining the seeds illustrated in Plate XXIII, Fig. 2, in which the six seeds to the left hand are of alfalfa and the five to the right of sweet clover, some suggestion may be afforded to this point. Perhaps the average person would experience considerable difficulty at first in distinguishing sweet clover seed in mixture, from such rounded alfalfa seeds as are seen here and there in Plate X, and as occur in the left-hand column in Plate XXIII, Fig. 1. There are, however, certain very clear and distinct differences. Examining the seeds of alfalfa in Plate XXIII, Fig. 2, it will be noticed that the scar, or "hilum," which marks the point of attachment of the seed to the pod, *is nearer the center of the seed than in the case of the sweet clover.* This is accompanied by the further fact that the "radicle" or embryonic root, which in each case forms a prominent "radicular ridge," as it may be called, on the edge of the seed running back from the hilum, is longer in the case of the sweet clover than in the case of alfalfa, as a general rule. The much greater prominence of the radicular ridge in sweet clover, together with the more swollen cotyledons or seed leaves, is further responsible for the greater depth of the "sinus" or groove, which marks the line where the radicle lies against the

cotyledons. It will further be noticed that this groove, which in sweet clover runs approximately parallel with the top of the radicular ridge, tends, in the case of alfalfa seeds, to run down at a diverging angle. See drawings in Plates XXXI and XXXIII.

After one has become accustomed to examining many seeds of the two species, the fact that the hilum, in the case of sweet clover, lies near the end of the seed opposite the radicle, while in alfalfa it is located almost invariably in the center of the seed, constitutes one of the most prominent distinguishing characters. If, now, the rounded seeds in Plate X be again examined, and compared with the sweet clover seeds in Plate XIV, this difference will become apparent, and further by comparison of the two species in Plate XXI. It will also be observed that whereas there are many alfalfa seeds of this short round type suggesting at first glance the seeds of sweet clover, a closer study reveals the fact that in the case of sweet clover, the radicular ridge runs off to the tip of the seed in a swelling curve, while in alfalfa seeds the corresponding ridge more nearly approaches a straight line, with the result that the tip of the alfalfa seed is pointed instead of rounded. *This is an almost infallible rule* to be relied upon in the detection of sweet clover seeds as distinguished from the somewhat similarly rounded and shortened seeds of alfalfa. So far as the kidney-bean type of alfalfa seed is concerned, there need never be confusion, since this type *never appears at all* in the seeds of sweet clover.

Medicago Lupulina, or yellow trefoil, appears, thus far, to constitute the principal substitute for alfalfa seed in cases called to the attention of this department, and in some respects it is the most dangerous adulterant and the most difficult of detection. The plant of yellow trefoil grows to about the same height as alfalfa, but the leaflets of the compound leaves are much shorter and broader at the tips than are those of alfalfa and, in fact, have much more of a "clover" aspect. (See Plate 11.) The flowers are borne in dense clustered racemes, are very much smaller than those of alfalfa, and are yellow in color. The pods are not coiled, as with alfalfa, although curved to form a single incomplete spiral. The pods are black when ripe and covered with a spiral network of prominent veins and are one-seeded. These pods are so distinctively different from the pods of *Medicago sativa* that no difficulty need be experienced in knowing the two species apart, where the pods are available. (See Plate V, Figs. 1 and 2, and the higher magnification in Plate VIII, Figs. 1 and 2.) With respect to the seeds, the distinctions are more subtle, and it is with the

seeds alone that the buyer has commonly to deal. The seeds of yellow trefoil average smaller in both directions than those of alfalfa, and in their general outlines they are usually oblong or orbicular. Plates XI and XIX will indicate sufficiently their chief characters, and Plate XVII, Fig. 2, shows three fairly representative seeds magnified to same proportions as the alfalfa seeds in Plates XV and XVI, Fgs. 1 and 2. The seeds of trefoil, in the case of the samples examined by the writers, while displaying to some extent the greenish cast of alfalfa seeds, show a greater admixture of yellow in the seed coat. The latter is always finely punctate as in alfalfa, and never warty as with sweet clover. Perhaps the first impression one receives from a careful comparison of trefoil seeds with those of alfalfa is that of their marked tendency to a round or oblong-oval shape. The hilum, it will be noticed, which, in the case of alfalfa, tends to be approximately at the center of the seed, *in trefoil always lies near the end where the tips of the cotyledons or seed leaves are found in the embryo.* (See Plate XVII, Fig. 2.) The hilum itself forms a much deeper notch than with alfalfa, and the radicular ridge, instead of rising in an ascending curve as with sweet clover, or slanting straight down toward the tip of the seed as in alfalfa, runs off in an approximately straight line, usually more or less parallel with the opposite edge of the seed, with a consequent result that the end of the seed which, in many cases, is pointed in alfalfa, in trefoil is fully rounded out. The seed as a whole is plumper than that of alfalfa, due to the greater convexity of the cotyledons, although this convexity is not so constant as is the case in sweet clover. It is often noticeable, in the case of trefoil, that a prominent central "beak" protrudes from the hilum edge of the seed. This is the point at which is located the micropyle, or opening by which the pollen tube entered the ovule at the time of fertilization, and through which the radicle gains egress when the seed germinates. This point is not nearly so prominent in seeds of alfalfa, for the reason that the radicular ridge runs directly back from the micropyle point, while in hop clover there is frequently a depression between the latter and the beginning of the ridge. (See drawings in Plate XXX and XXXI.) On this account the seeds of hop clover have so frequently, along the hilum edge, what has just been designated as a "beak," with a scalloped depression on either side of it, in which case the depression farthest away from the radicular ridge is the point of location of the hilum. In those seeds in which there is but a single depression, the radicular ridge runs straight away from the micropyle point without any intervening depression. In no

case do the seeds of trefoil seem to take the kidney form so frequent with alfalfa. This may perhaps be accounted for by the fact that with trefoil, but a single seed is borne in a pod which is not coiled, whereas in alfalfa the curvature of the seed may, to some extent, be accounted for by the spiral mode of development of the pod, and the flattening of the radicular ridge by the crowding of other adjoining seeds. In trefoil, it is further noticeable that the groove running along the base of the radicular ridge is not nearly so prominent as is the case in sweet clover. This, together with the difference in the markings of the seed coats, will assist in distinguishing such seeds of trefoil as are more nearly round from the seeds of sweet clover. It is clear that the botanical differences separating the seeds of *Medicago lupulina* from those of *Medicago sativa* are quite as characteristic and distinct as those which distinguish alfalfa itself from sweet clover. See also Plate XXII for general comparison of the species referred to.

The other species of *Medicago* which have come to the attention of the writers as an adulterant or substitute for alfalfa seed is *Medicago denticulata,* or bur clover (see Plate 111). So far as the plant of bur clover is concerned, it will be noticed that, the leaflets are much larger and broader at the apex than those of yellow trefoil and that at the point where the petiole or stem of the compound leaf joins the axis of the plant the "stipules" or leafy appendages are large, broad, and bordered with fine teeth, while in trefoil the same structures are narrow and lanceolate, ending in a single point. The flowers are much fewer on the flowering axis than in the case of alfalfa or of trefoil, are yellow in color, and of about the same size as those of trefoil, or less than a third the size of alfalfa flowers. The pods are large, spirally twisted in two or three flat coils, which are covered with a pattern of prominent reticulated veins, and which are armed at the edges with one or two rows of long, curved prickles, hooked at the tips, whence the name bur clover. These pods contain several seeds, which, in their appearance and general outline, more nearly resemble those of *Medicago sativa* than do the seeds of yellow trefoil. But there need not be the slightest difficulty in distinguishing them from alfalfa seeds, since their size, which is from a third to a half greater than that of the seeds of alfalfa, would clearly distinguish a bulk sample of bur clover from a bulk sample of alfalfa seed. With respect to the differences which distinguish the smaller seeds of bur clover from the larger seeds of alfalfa, distinctions that are practically a-Jailable for their recognition, cannot easily be given. Plates VI, Fig. 1 and IX, Fig. 1, will serve to indicate the ap-

pearance of the pods of bur clover, and Plates XII and XVII, Fig. 1, illustrate the seeds in magnifications corresponding to those of the species already discussed. See also for comparison the seeds of alfalfa and of bur clover in Plate XX.

Although *Medicago Arabica,* or spotted clover, has not yet been reported at this station as an adulterant of alfalfa, it occurs as an escaped plant, having been introduced with the other species, and there is no reason to suppose that it may not appear in alfalfa seed, so that a description of its character may be useful. The plant is an annual, like that of yellow trefoil and bur clover, and closely resembles the latter, but has generally a stouter habit of growth. It is better distinguished by the fact that the leaflets of the compound leaves have one or more dark spots near their centers. The stipules are similar to those of bur clover, flowers few, and the pods likewise coiled. The latter are, however, smaller than are the pods of bur clover, and the prickles are stouter and shorter. The seeds are smaller than those of bur clover, and as a rule narrower and longer than those of alfalfa, and with the "beak" a much more prominent and constant character of the seed than in the case of *Medicago lupulina.* Plates VI, Fig 2 and IX, Fig 2 will indicate the pod characters and Plates XIII and XVIII, Fig. 1, show the seeds at corresponding magnifications with the preceding species. It should be stated that so far as sweet clover is concerned as an adulterant, it is, in most cases and for most people, to be regarded as a weed. It is true that instances occur here and there where sweet clover is used as a forage plant, and valued as such, being reported to be eaten with avidity by stock. This is directly contrary, however, to the experience of most persons who have had occasion to observe and deal with the plant. Sweet clover, or *Melilotus,* contains in its leaves and stems, a bitter substance known as "cumarin," which is very generally distasteful to stock, and which causes them, commonly, to refuse to eat the plant unless compelled to do so by stress of hunger. The writers have made careful observations in pastures where sweet clover is abundant and have repeatedly found it entirely untouched, and growing in rank luxuriance, where the native prairie grass in its immediate vicinity was cropped to the ground. This observation has been substantiated repeatedly by the observations of others, and it is our belief that as a general thing, exceptional instances to the contrary notwithstanding, *Melilotus* is not relished by stock, and for the most part is rejected where other pasturage can be secured. On this account, there is serious objection to its appearance in alfalfa seed, and any admixture

should be guarded against. Indeed, *Melilotus* should be treated, so far as alfalfa is concerned, as a weed. It is usually not a difficult matter to go through an alfalfa field which is to be saved for seed, and to cut out the sweet clover plants with a scythe when they are in full bloom. This will usually end their life and prevent the ripened seed from being harvested and threshed with the alfalfa.

So far as an adulteration of alfalfa with bur clover and yellow trefoil is concerned, the offense is not so serious as if sweet clover were used, since these plants actually furnish a hay and forage crop similar in value to alfalfa, although less in quantity. Certainly the quality of the crop would be very similar to that of alfalfa. The main objection to the use of these species of *Medicago,* as adulterants of alfalfa, lies in the fact that the plants in question are but annuals, and, as was stated in the case of sweet clover, which is a biennial, their inferiority to a long-lived perennial, like alfalfa, other things being equal, is self evident. If it were the case that the yellow trefoil and bur-clover seed were always sold under their true names, there could be no possible objection to their introduction, or, indeed to that of any other of the many species of *Medicago,* since many of them have some forage value: but when we remember that, sowing at the rate of fifteen pounds to the acre, it costs about $2.50 an acre at the very least for alfalfa seed, as the market generally runs, it is self evident that where the species substituted, instead of living twenty years or more on the same ground, finishes its life history in a single season and renders the farmer dependent upon the annual appearance of self-sown plants, every means should be afforded for protecting buyers against deception, and the State, if necessary, should, by adequate legislation, in a pure seed and seed-control law, prevent the practice of adulteration and substitution in the case of this and other important crops.

From the results of the analyses of commercial alfalfa seed, made in this department, it appears that by far the greater portion of the impurities consists in the dead, decayed, immature and defective alfalfa seed itself. In very numerous cases, this factor alone amounts to from 8 per cent to 30 per cent of the samples submitted for analysis, while in the worst sample received during the past year, the amount of this dead seed reached 63 per cent.

To a certain extent, dead alfalfa seeds can be recognized by optical inspection, since in most cases their seed coats are brown or black, instead of yellow with a greenish tinge, which is the color of the live and healthy seed. It was therefore thought that

it might be possible, by mechanical analysis, to separate out the dead seeds, and give such an estimate of their average percentage in the total sample, as would convey an approximate idea of the actual value of the seed under investigation. The results however show that this cannot be done without leaving a wide margin of error, for the reason that not all of the seeds apparently good, so far as external appearances are concerned, will germinate, nor will all the apparently dead seeds fail to germinate. The results of actual germination tests indicate that in the case of alfafa, the percentage of ungerminated seeds remaining at the close of the test, often runs higher than would be indicated in the mechanical analysis; and that the separation and calculation of the percentage of seeds, which, by optical inspection, would confidently be recognized as dead, is too greatly subject to errors of judgment to be depended upon. Among the seeds apparently good and capable of germination there are many in which the embryo is too immature to grow, the seed having been gathered before having perfectly ripened. Often these immature seeds present a shrivelled appearance, but not invariably so. Nor is it, on the other hand, entirely certain that shrivelled seeds will not germinate. As illustration may be taken sample No. 77, in which the mechanical analysis resulted as follows:

	Per cent.
Medicago sativa, seed apparently good by optical inspection,	91.6
Impurities	8.4
Total	100.0
The impurities consisted as follows:	
Medicago sativa, dead, defective and immature seed	7.6
Foreign seed	.4
Inert matter	.4
Total	8.4

It would appear, therefore, from optical inspection, and removal of all the apparently dead seed, that there remained 91.6 per cent of the sample which might be expected to germinate. A germination test of the original sample, however, showed the actual germination percentage to be 78 per cent, or 13 per cent less than an optical inspection alone would have indicated. Subsequent analyses of lots taken from the original sample gave germination percentages of 79 and 74. (See Table I.) Furthermore, a germination test of the apparently dead and apparently immature seeds, taken together, showed 51 per cent germinating in six days, or 67 per cent if we add to this number one-third of those remaining hard at the close of the test. (See Table III.) A separate germination test also made of a separated lot of seeds of this sample, in which all were apparently good and viable, gave a final germination percent-

age of but 80. In other words, in an apparently perfectly sound lot of seeds of this sample, 20 per cent failed to germinate, and in an apparently bad lot of seeds, only 33 per cent failed to germinate. The results in this case sufficiently indicate the difficulty of detecting dead seed by optical inspection alone, although the investigations were carried on by persons especially experienced, and can be said to represent, in a degree, expert work. It was hoped at the outset that the margin of error would be sufficiently small in the mechanical separation of apparently non-viable seeds, so that a rule could be laid clown whereby an ordinary person might be enabled quickly to arrive at an approximate estimation of the value of the seed by simple mechanical analysis. It is evident to us, however, that for the present no such rule can be given; and that the only safe and satisfactory method of determining the value of an alfalfa seed sample is by an actual germination test. This, however, is in itself an extremely simple matter, and can be carried on by any individual or seed firm desiring knowledge regarding a sample of alfalfa, the purchase of which is under consideration. It may be well, therefore, to describe the most practical and convenient method of conducting the same.

In the first place, to be accurate, and to represent the facts correctly, the germination test must be made from a sample taken from a bulk lot in such a manner as to be genuinely representative. In experiment stations an instrument called a sampler is used for this purpose. Lacking this, the best way is to take with the hand at random, small samples from different places and at different depths in the bulk lot of seed. These several small samples should be mixed together, and this, too, is done at our Experiment Station by means of a mechanical mixer, the principle of which is illustrated by revolving a bottle containing the seed, in which the volume of the seed does not much more than half fill the container, slowly on its long axis, and while doing so alternately elevating either end of the bottle. By this means the different constituents in the sample will become thoroughly mixed and uniform throughout. This mixing process can be accomplished, although of course less easily, by revolving the container in the hand as indicated.

From such a thoroughly mixed sample of seed, 100 seeds are counted out at random for the germination test. And here again methods of precision are desirable. Almost unconsciously, in selecting seeds for a germination test, the larger and better appearing seeds will be selected in preference to the others. To eliminate this element of personal choice, in all the germination tests made

by this department, the selection of the 100 seeds is made by weight. From the sample as it comes from the mixer, the seeds are poured into a pan of the balance until they bring into equilibrium a weight on the opposite pan known to slightly more than equal the weight of 100 seeds. As a matter of fact, the average number thus obtained was 106 seeds at a weighing. By these precautions it will be seen that in the official seed analyses made in this laboratory it is endeavored in every way to eliminate the element of personal error. The further precaution is usually taken of making several distinct germination tests from the same sample.

Naturally the average private individual cannot ordinarily make use of methods of extreme precision, and must rely upon the law of averages for the accuracy of his results. It is advised, therefore, in making germination tests, that several lots of 100 seeds each be taken from the same sample and germinated at the same time and under the same conditions. Each lot of seeds should be placed between sheets of moist blotting paper or cloth (preferably such as has been boiled to prevent the growth of moulds and bacteria) and the whole placed in a moist chamber formed by inverting one common earthenware plate over another. During the test the samples should be kept at a temperature of 20° Centigrade (68° Fahr.). At the end of the third day from the time of the commencement of the test, the seeds that have germinated should be removed and counted. This suffices for forming a preliminary judgment regarding the character of the sample, and may often be sufficient for practical purposes, as for instance, when the number which have germinated by that time is 80 or above, as frequently happens. Where the number falls below 80, make a second count of the germinated seeds at the end of the sixth day. Then, to the total number that have germinated, add arbitrarily one-third of the seeds remaining hard at the close of the test, and the final result will be the germination percentage, according to the rules adopted by the standing committee on methods of seed testing, of the Association of American Agricultural Colleges and Experiment Stations, and in use in the United States Department of Agriculture and the experiment stations generally. The reason why it is recommended that the germination test be discontinued at the end of the third day, if 80 per cent of the seed have germinated by that time, is because of the fact that, as alfalfa seed sells on the market, the buyer pays the same price for commercial seed in which the germination percentage ranges all the way from 80 to 100 per cent, and therefore there is nothing to be lost and usually nothing to be gained under the present crude condition of grading alfalfa seed,

by the prospective buyer carrying the germination test to its final conclusion, unless the percentage at the end of the third day runs lower than 80.

It has been found by experiment that the results obtained by germination tests in a moist chamber with blotting paper do not correspond exactly to those resulting from germination tests in soil. If it is desired to make a soil test, the method should be as follows: Sterilize good garden soil by baking at oven temperature in a covered pan to retain the moisture. By this means, most of the seeds of weeds will be killed, as well as most of the bacteria and other fungi existing in the soil. Sow the alfalfa seeds not more than one-half inch deep, in 100 seed lots, in covered boxes (cigar boxes will do). In this case the germination test will have to be prolonged until no more alfalfa seedlings appear above the surface of the soil.

The following tables give the results of germination tests with 21 different samples of alfalfa seeds recently received by this department from different sources. Table I represents the results obtained from duplicate tests with the original samples, while Tables II and III give the results of germination tests of separated lots of seeds from the same samples, in which the seeds that appeared dead, defective and immature were separated from those that appeared sound and viable, each lot being subjected to a separate and distinct germination test. There is great variability in the results shown in Tables II and III due probably in part to the fact that in separating the lots in question, the judgment must frequently have erred, especially in the matter of the immature seeds apparently not viable. As is seen by reference to the table, an average of 47 per cent of the seeds of all the samples of the apparently bad seeds, germinated, or 65 per cent if we add one-third of the seeds remaining hard at the close of the test. The ranges seem to be very great, from 39 to 80 per cent. To eliminate all possible sources of experimental error, each lot of seed was mechanically mixed and the one hundred seed lots weighed out, as previously described. Further to eliminate the personal equation, it was arranged for a single person to make all the experimental tests and counts. Nevertheless, it is evident that the data embodied in Tables II and III are too few and too contradictory to serve as a basis for anything but the most general inference. It indicates sufficiently, however, how difficult it is even for a skilled and trained person to determine by optical inspection alone what seeds in a sample are not viable.

Table II also shows that the judgment is subject to a consider-

able margin of error, although not so broad a one, in selecting apparently sound and viable seeds. The range of germination percentages ascertained in these samples was from 74 to 100, while the average was 90 per cent, indicating that in the long run about 90 per cent of the seed that *appear* sound will actually germinate, although here again the number of samples tested is too few for the computation of an absolutely safe average.

A further comparison of results in individual cases, as shown by Tables II and III, indicates that in those samples in which the germination percentage ran high in the separated good seed, it also ran high in the corresponding lots of separated seed apparently not viable, and *vice versa.* For example, taking five samples in which the germination percentage of the separated good seed ran high, the corresponding lots of separated seed apparently not viable showed higher germination percentages than in the four cases following, in which the separated good seed ran comparatively low in germination percentage.

HIGH-GRADE SEED.

Analysis No.	Germination per cent of seed apparently viable.	Germination per cent of seed apparently not viable.
23	100	70
37	99	63
52	98	80
10	97	73
11	96	64

LOW-GRADE SEED

Analysis No.	Germination per cent of seed apparently viable.	Germination per cent of seed apparently not viable.
17	74	48
20	75	44
56	75	39
25	77	52

TABLE I.—ORIGINAL SAMPLES, AFTER REMOVAL OF WEED SEEDS AND INERT MATTER.

Seed analysis No.	Germination test No.	Lot No.	Test begun	Test completed	Number germinating in successive days of the test.							Total number germinated	Per cent	No. hard at close of test	Per cent	Total viable seeds estimated	Per cent
					1	2	3	4	5	6	7						
10	27	1	Dec. 26	Jan. 2	0	66	3	8	0	2	0	79	79	21	21	86	86
10	27	2	Dec. 27	Jan. 3	0	67	2	0	0	0	0	69	69	31	31	79	79
11	28	1	Dec. 26	Jan. 2	0	78	3	0	0	0	1	82	82	18	18	88	88
11	28	2	Dec. 27	Jan. 3	0	60	7	0	0	0	1	68	68	32	32	79	79
17	29	1	Dec. 26	Jan. 2	0	32	7	2	0	3	1	45	45	55	55	63	63
17	29	2	Dec. 27	Jan. 3	0	31	7	0	7	0	1	46	46	54	54	64	64
18	30	1	Dec. 26	Jan. 2	0	92	3	0	0	0	0	95	95	5	5	97	97
18	30	2	Dec. 27	Jan. 3	0	93	1	0	0	0	0	94	94	6	6	96	96
20	31	1	Dec. 26	Jan. 2	0	40	11	5	0	0	0	56	56	44	44	71	71
20	31	2	Dec. 27	Jan. 3	0	33	3	0	5	0	0	41	41	59	59	61	61
21	32	1	Dec. 26	Jan. 2	0	67	6	2	0	0	0	75	75	25	25	83	83
21	32	2	Dec. 27	Jan. 3	0	69	10	0	1	0	0	80	80	20	20	87	87
23	33	1	Dec. 26	Jan. 2	0	70	6	2	0	1	0	79	79	21	21	86	86
23	33	2	Dec. 27	Jan. 3	0	89	1	0	0	0	0	90	90	10	10	93	93
25	34	1	Dec. 26	Jan. 2	0	45	11	1	0	0	0	57	57	43	43	71	71
25	34	2	Dec. 27	Jan. 3	0	36	10	0	4	3	1	54	54	46	46	69	69
29	35	1	Dec. 26	Jan. 2	0	88	3	0	0	0	0	91	91	9	9	94	94
29	35	2	Dec. 27	Jan. 3	0	82	2	0	2	0	1	87	87	13	13	91	91
35	36	1	Dec. 26	Jan. 2	0	58	22	3	0	2	0	85	85	15	15	90	90
35	36	2	Dec. 27	Jan. 3	0	63	10	0	3	0	0	76	76	24	24	84	84
37	37	1	Dec. 26	Jan. 2	0	44	23	4	0	0	0	71	71	29	29	81	81
37	37	2	Dec. 27	Jan. 3	0	55	13	0	7	0	1	76	76	24	24	84	84
46	38	1	Dec. 26	Jan. 2	0	69	5	3	0	0	0	77	77	23	23	85	85
46	38	2	Dec. 27	Jan. 3	0	69	6	0	4	0	0	79	79	21	21	86	86
52	39	1	Dec. 26	Jan. 2	0	74	12	1	0	0	0	87	87	13	13	91	91
52	39	2	Dec. 27	Jan. 3	0	88	5	0	1	0	0	94	94	6	6	96	96
53	40	1	Dec. 26	Jan. 2	0	86	4	0	0	0	1	91	91	9	9	94	94
53	40	2	Dec. 27	Jan. 3	0	82	1	0	0	1	0	84	84	16	16	89	89
56	41	1	Dec. 26	Jan. 2	0	54	18	6	0	7	1	86	86	14	14	91	91
56	41	2	Dec. 27	Jan. 3	0	49	5	0	1	1	0	56	56	44	44	71	71
58	42	1	Dec. 26	Jan. 2	0	67	9	4	0	3	1	84	84	16	16	89	89
58	42	2	Dec. 27	Jan. 3	0	58	3	0	3	0	1	65	65	35	35	77	77
65	43	1	Dec. 26	Jan. 2	0	53	6	5	0	1	0	65	65	35	35	77	77
65	43	2	Dec. 27	Jan. 3	0	48	6	0	1	0	1	56	56	44	44	71	71
74	44	1	Dec. 26	Jan. 2	0	77	10	4	0	0	0	91	91	9	9	94	94
74	44	2	Dec. 27	Jan. 3	0	82	2	0	5	0	0	89	89	11	11	93	93
76	45	1	Dec. 26	Jan. 2	0	62	9	0	0	0	0	71	71	29	29	81	81
76	45	2	Dec. 27	Jan. 3	0	56	8	0	1	0	1	66	66	34	34	77	77
77	46	1	Dec. 26	Jan. 2	0	49	12	5	0	3	0	69	69	31	31	79	79
77	46	2	Dec. 27	Jan. 3	0	49	7	0	3	0	2	61	61	39	39	74	74
78	47	1	Dec. 26	Jan. 2	0	33	22	10	0	8	1	74	74	26	26	83	83
78	47	2	Dec. 27	Jan. 3	0	37	17	0	7	0	1	62	62	38	38	75	75
Average					0	62	8	2	1	0	0	74	74	33	33	83	83

TABLE II—GOOD SEED SEPARATED BY OPTICAL INSPECTION; APPARENTLY ALL VIABLE.

Seed analysis No.	Germination test No.	Lot No.	Test begun	Test completed	Number germinating in successive days of the test. 1	2	3	4	5	6	7	Total number germinated	Per cent.	No. hard at close of test	Per cent.	Total viable seeds estimated	Per cent.
10	48	1	Dec. 28	Jan. 3	0	90	0	6	0	0	0	96	96	4	4	98	98
11	50	1	Dec. 28	Jan. 3	0	72	0	23	0	0	0	95	95	5	5	97	97
17	52	1	Dec. 29	Jan. 4	0	0	52	6	1	2	0	61	61	39	39	74	74
18	54	1	Dec. 29	Jan. 4	0	0	92	1	0	1	0	94	94	6	6	96	96
20	56	1	Dec. 29	Jan. 4	0	0	47	10	6	0	0	63	63	37	37	75	75
21	58	1	Dec. 29	Jan. 4	0	0	86	2	2	1	0	91	91	9	9	94	94
23	60	1	Dec. 29	Jan. 4	0	0	97	1	2	0	0	100	100	0	0	100	100
25	62	1	Dec. 29	Jan. 4	0	38	10	15	3	0	0	66	66	34	34	77	77
29	64	1	Dec. 30	Jan. 5	0	86	3	2	0	0	0	91	91	9	9	94	94
35	68	1	Dec. 30	Jan. 5	0	52	23	11	1	2	0	89	89	11	11	93	93
37	70	1	Jan. 2	Jan. 8	0	70	23	6	0	0	0	99	99	1	1	99	99
46	72	1	Jan. 2	Jan. 8	0	57	16	11	0	0	0	84	84	16	16	89	89
52	74	1	Jan. 2	Jan. 8	0	79	17	1	0	0	0	97	97	3	3	98	98
53	76	1	Jan. 2	Jan. 8	0	98	1	0	0	0	0	99	99	1	1	99	99
56	80	1	Jan. 2	Jan. 8	0	43	17	1	0	2	0	63	63	37	37	75	75
58	84	1	Jan. 8	Jan. 15	0	86	3	1	2	0	2	94	94	6	6	96	96
65	86	1	Jan. 8	Jan. 15	0	73	11	0	2	0	3	89	89	11	11	93	93
74	88	1	Jan. 8	Jan 15	0	66	18	7	0	0	0	91	91	9	9	94	94
76	90	1	Jan. 8	Jan. 15	0	60	13	2	0	0	1	76	76	24	24	84	84
77	92	1	Jan. 8	Jan. 15	0	55	6	7	0	0	2	70	70	30	30	80	80
78	94	1	Jan. 8	Jan. 15	0	51	23	4	1	0	1	80	80	20	20	87	87
Average					0	51	27	6	0	0	0	85	85	14	14	90	90

TABLE III—BROWN, BLACKENED, AND GREEN IMMATURE SEED SEPARATED BY OPTICAL INSPECTION; APPARENTLY NOT VIABLE.

Seed analysis No.	Germination test No.	Lot No.	Test begun	Test completed	Number germinating in successive days of the test. 1	2	3	4	5	6	7	Total number germinated	Per cent.	No. hard at close of test	Per cent.	Total viable seeds estimated	Per cent.
10	49	1	Dec. 28	Jan. 3	0	35	21	1	3	0	0	60	60	40	40	73	73
11	51	1	Dec. 28	Jan. 3	0	30	0	14	1	1	0	46	46	54	54	64	64
17	53	1	Dec. 29	Jan. 4	0	0	15	4	1	3	0	23	23	77	77	49	49
18	55	1	Dec. 29	Jan. 4	0	0	34	1	2	1	0	38	38	62	62	59	59
20	57	1	Dec. 29	Jan. 4	0	0	15	1	1	0	0	17	17	83	83	45	45
21	59	1	Dec. 29	Jan. 4	0	0	38	7	3	0	0	48	48	52	52	65	65
23	61	1	Dec. 29	Jan. 4	0	0	51	2	2	0	0	55	55	45	45	70	70
25	63	1	Dec. 29	Jan. 4	0	12	6	10	1	0	0	29	29	71	71	53	53
29	65	1	Dec. 30	Jan. 5	0	34	14	4	1	5	0	58	58	42	42	72	72
35	69	1	Dec. 30	Jan. 5	0	42	10	4	0	1	0	57	57	43	43	71	71
37	71	1	Jan. 2	Jan. 8	0	24	14	4	0	3	0	45	45	55	55	63	63
46	73	1	Jan. 2	Jan. 8	0	40	7	2	0	0	0	49	49	51	51	66	66
52	75	1	Jan. 2	Jan. 8	0	55	14	1	0	0	0	70	70	30	30	80	80
53	77	1	Jan. 2	Jan. 8	0	49	15	2	0	0	0	66	66	34	34	77	77
56	81	1	Jan. 2	Jan. 8	0	2	4	1	0	2	0	9	9	91	91	39	39
58	85	1	Jan. 8	Jan. 15	0	41	7	3	0	0	0	51	51	49	49	67	67
65	87	1	Jan. 8	Jan. 15	0	17	15	3	2	0	0	37	37	63	63	58	58
74	89	1	Jan. 8	Jan. 15	0	53	14	0	1	0	0	68	68	32	32	79	79
76	91	1	Jan. 8	Jan. 15	0	45	7	2	0	0	1	55	55	45	45	70	70
77	93	1	Jan. 8	Jan. 15	0	40	4	3	2	0	2	51	51	49	49	67	67
78	95	1	Jan. 8	Jan. 15	0	42	13	6	2	0	0	63	63	37	37	75	75
Average					0	27	15	4	1	0	0	47	47	53	53	65	65

TABLE IV.

Seed Analysis No.	Received From.	Date. 1905.	Mechanical Analysis.				Germination Test.			
			Seed judged viable	Seed judged not viable	Foreign Seed	Inert Matter	Original Sample. Lot No. 1.	Original Sample. Lot No. 2.	Separated Good Seed	Separated Bad Seed
10	Mitchelhill Bros., St. Joseph, Mo.	Mar.	74.0	24.0	1.2	0.8	86	79⅛	97⅜	73⅛
20	Jennings & Moore, Ellsworth, Kan.	Aug. 21	82.6	13.0	3.8	0.6	70⅜	60⅜	75⅛	44⅜
21	Mitchelhill Bros., St. Joseph, Mo.	Aug. 21	72.3	26.1	0.8	0.8	83⅛	86⅜	94	65⅛
23	J. F. Bacon, White City, Kan.	Aug. 14	83.0	10.0	6.0	1.0	86	93¼	100	70
25	Al. Conley, El Dorado, Kan.	Aug. 30	72.0	26.0	0.8	1.2	71⅛	illegible	illegible	illegible
29	F. Barteldes & Co., Lawrence, Kan.	Sept. 30	91.2	8.2	0.6	0.0	94	illegible	illegible	illegible
35	Geo. F. Edson, Olathe, Kan.	Sept. 23	79.0	15.0	4.0	2.0	90	84	92⅜	71⅛
37	G. N. Pew, Plevna, Kan.	Sept. 26	66.0	24.0	8.0	2.0	80⅜	84	99⅛	63⅛
46	J. C. Ball, Gardner, Kan.	Sept. 29	93.6	6.2	0.2	0.0	84⅜	86	89⅛	66
52	Missouri Seed Co., Kansas City, Mo.	Oct. 18	95.6	4.4	0.0	0.0	91⅛	96	98	80
53	Missouri Seed Co., Kansas City, Mo.	Oct. 18	93.7	5.5	0.2	0.6	94	89⅛	99⅛	77⅛
56	James Rogers, Peru, Kan.	Oct. 5	77.0	16.0	5.0	2.0	90⅜	70⅜	75⅜	39⅜
58	John Anderson, Plevna, Kan.	Oct. 7	69.2	24.7	4.6	1.5	82⅛	76⅜	96	67⅛
65	F. Barteldes & Co., Lawrence, Kan.	Oct. 10	78.8	19.4	1.4	0.4	76⅜	70⅜	92⅜	58
74	Geo. T. Fielding & Sons, Manhattan	Oct.	87.0	10.9	0.1	2.0	94	92⅜	94	78⅜
76	F. Barteldes & Co., Lawrence, Kan.	Oct. 25	85.9	12.3	1.4	0.4	80⅜	77⅜	84	70
77	F. Barteldes & Co., Lawrence, Kan.	Oct. 25	91.6	7.6	0.4	0.4	79⅛	74	80	67⅛
78	F. Barteldes & Co., Lawrence, Kan.	Oct. 25	91.3	8.0	0.2	0.5	82⅛	74⅜	86⅜	75⅛

Table IV gives in parallel columns, the comparative results of mechanical analyses and germination tests of identical samples. In the columns under "Mechanical Analysis," entitled "Seed judged viable" and "Seed judged not viable," are to be understood as included, the results of the analyses of the original samples by optical inspection alone, in which the attempt was made to separate, by means of their external appearance, the seeds supposed to be viable from those supposed to be not viable. It was supposed that by this means a possible practical rule might be deduced, whereby the general result of the germination test might be anticipated in a rough way. The results in general thus far, as has already been stated, do not justify the expectation that such a method can safely be proposed, owing to the variability of individual judgments as to what constitutes viable seed. While some of the mechanical analyses, such as numbers 25, 29, 52, 53, and 65, run closely parallel to the actual results of the germination tests, most of the others vary more or less widely from them and indicate the general unsafeness of the method.

In the columns under "Germination Tests" are included two columns entitled "Separated Good Seed" and "Separated Bad Seed," respectively. The results herein represent the actual germination tests which were carried on upon separated lots of seed which appeared to be respectively viable and not viable. These results simply confirm the general conclusion just stated, derived from a comparison of the mechanical analyses with the germina-

tion tests of the original samples, as set forth in the columns headed "Lot No. 1" and "Lot No. 2." It will be seen, for instance, upon casting the eye down the column entitled "Separated Good Seed," that while it was possible to arrive at a tolerably high degree of accuracy with respect to the seeds retained under this caption, on the other hand, a reference to the corresponding results in the column entitled "Separated Bad Seed" indicates how very greatly the judgment erred in the attempt to separate bad seed by optical inspection. In one case, sample No. 52, as many as 80 per cent of the seed separated as bad, germinated, and the most accurate "guess," in sample No. 56, was found to have included in the rejected lot of supposed bad seed, as much as 39⅓ per cent of seed that actually did germinate.

The fact that the results of the germination tests as exhibited in lots 1 and 2 of the original samples do not more closely approximate is probably to be ascribed to the fact that, lacking a proper incubator or germinating chamber at the time (December, 1904), it was necessary to conduct the tests in the laboratory, at the room temperature, which fluctuated more or less, especially at night.

From these comparisons it would also appear that in a *poor* sample of seed, even those seeds which, so far as external appearances indicate, are perfectly good and viable, are liable to have a low germination percentage, indicating that the embryo may be affected by external conditions in such a way as to destroy its vitality without the results becoming evident in the seed coat.

The high degree of error seen in the judgments upon the apparently bad seed is probably also to be ascribed in part to the rejection as not viable of green seeds that were deemed too immature to grow. If only the blackened seed had been rejected, it is likely that the margin of error would have been much smaller.

It was thought that it might be possible to distinguish the good and bad alfalfa seed by a specific gravity test, but so far the indications are negative, and the germination test therefore remains as the only final criterion of the quality of the seed; nor does a specific gravity test suffice to differentiate the seeds of yellow trefoil from those of alfalfa, both having a specific gravity of 1.25 sweet clover seeds are somewhat heavier, having a specific gravity of 1.33.

As alfalfa is sold in the market at the present time, it is frequently the case that different lots of seed sold for the same price will differ very widely in germination percentage, ranging on the average, from below 80 per cent to 96 per cent and above. This is an extremely crude state of affairs, and represents a primitive

condition which calls for improvement. The grading of alfalfa seed should rest upon facts which an adequate germination test alone will reveal. In the case of seed houses, the time required for the conclusion of this test (six days), may seem irksome, and in such cases, as has been stated, an approximation to the accuracy of the six-day test can be obtained from a preliminary test concluded at the end of the third day. So far as our results go, the indications are that about 80 per cent of the seeds will have germinated by that time. A more accurate method of grading alfalfa seed than the existing one is not the only feature of the seed bnsiness that calls for reform. It is further obligatory upon every seed firm to sell nothing but alfalfa under the name of alfalfa. A cheap, low-grade sample of alfalfa, seed may reasonably be expected to contain a certain amount of debris, weed seed, and dead or immature alfalfa seed, but it should not contain any conscious substitutes. Where, as in a number of cases that have come to the attention of this department, alfalfa seed has been sold in which the seed of yellow trefoil or bur clover was substituted therefor in whole or in part, restitution should be insisted upon by the purchaser.

So far as the weed seeds present in alfalfa are concerned, it seems reasonable to demand that they should not exceed. one and one-haif per cent of the total. (This, by the way, is the total percentage of all impurities allowed in the seed laboratories of the German Experiment Stations). Following is a list of the weeds, the seeds of which have been most constantly present in the samples of alfalfa examined at this station during the past year:

Plantago lanceolata (Buckhorn or Ribbed plantain).
Rumex obtusifolia (Bitter dock).
Rumex crispus (Curled dock).
Chenompodium album (Lamb's-quarter).
Melilotus dlba (Sweet clover).
Choetochloa viridis (Green foxtail).
Syntherisma sanguinalis (Crab grass).
Plantago Rugellii (Rugell's plantain).
amaranthus retroflexus (Pigweed).
Choetochloa glacua (Yellow foxtail).
Rumex acetosell (Sheep's-sorrel).
Rumex altissimus (Smooth clock).

and occasional seeds of about ten other species. Of the above, the character of sweet clover has been alluded to. The weed most constantly present is the English plantain, or ribbed plantain, locally and rather more commonly known in the west as "Buckhorn." (See Plate XXIX.) This is a weed of the plantain genus,

which is distinctly objectionable. It is a perennial plant, naturalized from Europe, and is most commonly found in alfalfa seeds imported from European countries, and especially from Germany. In general, it resembles the other native plantains, but has much narrower and longer leaves. It fruits freely, and of course cannot be eradicated by mowing, particularly since the leaves form a rosette close to the ground. The docks, belonging to the genus *Rumex,* are also objectionable, the smooth, bitter and curled docks being all perennials, extremely troublesome weeds, and difficult to eradicate, especially in land that is inclined to be low and wet. Fortunately, the seeds of dock, like those of the plantains, can very easily be recognized. They are shining, black in color, and of triangular outline. They are seen ilustrated in Plate XXVII.

Most of the other weeds represented are either annuals, or perennials of infrequent occurrence. Some of them, like the crab grass and foxtail (particularly the former), give considerable trouble in newly sown alfalfa fields. The annual weeds can usually be easily eliminated by successive mowings, but the perennials can only be eradicated by digging out. Occasionally dodder may become a dangerous weed in an alfalfa field, but in the samples received here, dodder seeds have only occasionally been present.

In general it may be stated that the weeds most to be feared and watched for, as alfalfa, seed runs in the western markets at the present time, are the buckhorn and the various species of the docks, seeds of both of which should easily be recognized from the illustrations referred to.

Perhaps it will be interesting to consider the results of some of the analyses. In general, as was stated previously, it may be said that the common fault to be found with alfalfa, seed on the market lies in the large amount) of immature, dead and decayed seed so frequently present. In one case the dead and defective seed of alfalfa reached 60 per cent of the total from 5 to 10 per cent being very common in the samples analyzed. The best sample of alfalfa seed received, analyzed 95.6 per cent pure, and apparently sound seed of the species, with but 4.4 per cent of all impurities, which latter consisted entirely of dead alfalfa seed, there being but a trace of foreign seed and inert matter in the sample. The germination test of the sample showed 93 per cent of the seed capable of germination. One of the very worst samples received showed but 63.9 per cent of pure, good alfalfa seed, while the impurities amounted to 36.1 per cent, and consisted of dead and decayed alfalfa, seed, 28.1 per cent; foreign seed, 7.1 per cent; and inert mat-

ter, .9 per cent. Such a collection of weed seeds as was compressed into this sample one would go far to seek.

	Seeds.
Yellow trefoil	126
Rugell's plantain	21
Ribbed plantain	18
Crab grass	16
Red clover	8
Yellow foxtail	7
Sweet clover	5
Witch grass	5
Timothy	5
Lamb's-quarter	4
Pigweed	3
False mallow	3
Hoarhound	1
Peppergrass	1
Wild carrot	1
English blue-grass	1
Wild verbena	1
Spurge	1

All of the above came from a sample weighing five grams, or .18 oz. avoirdupois, the standard amount used for making purity tests.

Let us examine the results in this case. There are about 211,350 alfalfa seeds in a pound. In a pound of seed of the character analyzed there would be as follows:

Good alfalfa seed, capable of germinating	135,053
Dead and defective alfalfa seed, incapable of germinating,	59,389
Foreign seeds of all kinds	20,593
Of these, the trefoil seeds would amount to	11,326
Plantain and crab grass seeds	4,942

Sowing at the rate of fifteen pounds to the acre, with an absolutely pure sample of alfalfa seed, there would be, if equally distributed, seventy-three alfalfa seeds sown on every square foot of ground. The amount of impurities in this sample would reduce the number of the alfalfa seeds to the square foot to forty-six, and would substitute for good alfalfa seven foreign seeds for every square foot. The positive damage possible is evident here when we consider that these weed seeds are paid for and are added to the weed seeds already existing in the soil; and that very frequently they are perennial weeds of a nature very difficult to eradicate. If alfalfa seed costs seventeen cents a pound, there would have been, in a case like this, as much as six cents absolutely thrown away for every pound of the seed bought; and to the amount thus lost must be added the rental value of the land occupied by the weeds, the seeds of which have been bought and sowed. Of course, in the instance under consideration, the plants of the yellow trefoil are not to be considered as weeds although they are greatly inferior to alfalfa in value, but in many other instances which have come to our attention, the total of the foreign

seed belonged to entirely useless or noxious plants. For example, in another sample of alfalfa seed, in which the foreign seed ran as high as 5 per cent of the total, there were 294 foreign seeds in the five-gram sample analyzed, of which only five could, by any possibility, be considered of value.

Most of the alfalfa seed sold in Kansas comes directly or indirectly from western seed houses. Lesser amounts are imported from Europe, chiefly from Germany. It is claimed by the seedsmen that most of the adulterated alfalfa seed on the market comes from the latter source. Of the correctness of this statement, we are not at present in a condition to judge.

It may be said that in all cases in which this department has entered into correspondence with seed firms with respect to the quality of their seeds, they have invariably been found willing to do all in their power to remedy existing evils, and to secure pure seed for their customers. Many of the western seedhouses doing business in Kansas are sending their samples of alfalfa and other commercial seed quite regularly to this Station for analysis.

This much must always be remembered by the buyer, that pure seed costs more to put on the market than poor seed; that the seeds of the different staple crops, including alfalfa and the grasses, exist on the market in several grades, and that the quality and purity of the seed in question depends very largely, in the first instance, upon the grade of seed purchased. Perfectly ripe alfalfa seed, free from light, immature or dead seed, weed seeds and debris: costs more than the lower grades to put on the market. If buyers insist upon cheapness as the first requisite of the seed purchased, they are in no positioin to complain as to its quality, except in so far as the seed may happen to be adulterated.

Finally, it should be generally known throughout the State that the Experiment Station maintains a seed laboratory for the purpose of investigating and analyzing commercial seeds, and that purity and germination tests of seeds will be made by the Botanical Department, without charge to any citizen of the State. The methods of analysis as practiced here are as follows:

The entire history of the sample received is entered upon a mecchanical analysis record sheet No. 1, as follows:

MECHANICAL SEED ANALYSIS
RECORD SHEET NO. 1.

Seed Analysis No. , Herbarium No. , Sender's Mark

Received , 19

Sent by

Address

Sender's Letter, Date 19

Letter File No.

Our Reply, Date 19

Letter Book No. , P.

Seed Purchased 19

By , as

From , of

Wholesale and Retail Seed House
Local Retail Dealer
Private Party

Who Purchased Same, , 19 , of

of

Wholesale and Retail House
Local Retail Dealer
Private Party

Price Paid by Grower

Amount of Land Planted

General Results

Remarks

Herein is entered a complete history of the sample, so far as it is obtainable. This sheet is filed in the office for reference. The sample is them sent to the seed laboratory for mechanical analysis. The original sample as received, is mixed in the manner already described in this bulletin, and from the thoroughly mixed sample five grams, in the case of alfalfa, are weighed out. This amount is then carefully separated into four distinct lots, comprising, respectively, the sound seed of the species, the apparently dead or defective seed, the foreign seed, and the inert matter. Each of these separated lots is then weighed, the percentages calculated and the results entered upon mechanical seed analysis record sheet No. 2 which also admits of the entry of the species and proportions of the foreign seeds in the sample.

MECHANICAL SEED ANALYSIS
RECORD SHEET NO 2

Analysis by _____ 19__

Wt. of Sample Analyzed _____

	Wt. Grams	%
1. Sound Seed True to Name		
2. Dead or Defective Seed		
3. Foreign Seed		
4. Inert Matter		

Total %

Sound Seed _____

All Impurities _____

Total 100 %

Foreign Seed, Classified

NAME	No.	%	% of Total

Of this sheet, two copies are made—one for the office file and one for report to the sender of the sample. In the meantime the original sample has been subjected to a germination test, in which one or more lots of 100 seeds each are weighed out for testing in a germinator. The results are entered upon the seed germination record sheet. Two copies of this germination sheet are likewise made, one for filing and one for report. It will be observed that the

Seed Germination Record Sheet

Seed Analysis No. _____ Germination Test No. _____

Original Sample _____
Separated Pure Seed _____
Separated Defective Seed _____

Lot No.	TEST BROUN	Made by _____ Completed _____ 19	NO. ELEMENTS NOTED	%	NO. NOTED AT CLOSE OF TEST	%	NO. GERMINATED AT 15 DAYS	%
		Germinated in _____ Temp. C						
Day of Test.								
No. Seeds Germ.								
Lot No	TEST BROUN	Made by _____ Completed _____ 19						
		Germinated in _____ Temp. C.						
Day of Test.								
No. Seeds Germ.								
Lot No	TEST BROUN	Made by _____ Completed _____ 19						
		Germinated in _____ Temp. C.						
Day of Test								
No. Seeds Germ.								
Lot No	TEST BROUN	Made by _____ Completed _____ 19						
		Germinated in _____ Temp. C.						
Day of Test.								
No. Seeds Germ.								
		Total Average						

record sheets designed by the Botanical Department of this Station differ in a number of particulars with respect to form and arrangement from those in use in the Seed Laboratory of the Bureau of Plant Industry, United States Department of Agriculture, described in circular No. 34 (Revised) of the Office of Experiment Stations. Our sheet's are 5 x 8 inches in size, perforated at one end, and filed in a loose-leaf binder.

SUMMARY.

1. The chief adulterants found in alfalfa seed, upon the western market at the present time is yellow trefoil (Medicago lupulina), although there are occasional instances in which bur clover (Medicago denticulata and sweet clover *(Melilotus alba)* also occur.

2. The seeds of these three species cannot be distinguished from the seeds of alfalfa by casual inspection, unless present in considerable quantities.

3. Their detection in smaller quantities is impossible except to a trained observer, using a lens magnifying from 15 to 20 diameters.

4. The objection to yellow trefoil and bur clover as adulterants is due not so much to the inferior quality of the forage produced by these plants as to the fact that they are annual plants, whereas alfalfa is perennial, and the expense of reseeding need not be undergone short of 15 or 20 years or more, where a good stand has once been secured. Sweet clover is objectionable as an

adulterant for the reason that it is only a biennial and is generally distasteful to stock.

5. The chief impurity in alfalfa seed upon the western market is the dead seed of alfalfa itself, the amount of inert matter or debris being relatively less than in average commercial lots of grass seed.

6. The obnoxious weed seeds in the alfalfa seed marketed in Kansas last year were chiefly those of species of docks and the English plantain, *Plantago lanceolata),*

7. The separation of dead alfalfa seed by optical inspection has not been found practically possible; so that it cannot be recommended as a safe method of analysis. Nor has the separation of good and bad seed by the specific gravity test been found practically satisfactory.

8. The range of germination percentage in commercial alfalfa samples runs all the way from 60 to 96 per cent, with an average of about 83 per cent. The grading of alfalfa seed should be based upon actual germination tests.

9. The loss to growers because of impurities in alfalfa seed, very commonly reaches 10 per cent of the total and is often 30 per cent and over.

10. This loss can be prevented by buyers subjecting alfalfa seed, the purchase of which is contemplated, to a purity analysis and a germination test, both of which will be performed for any citizen of Kansas without charge, by the Botanical Department of the Kansas Experiment Station.

11. There is imperative need for the maintenance by the State, at the Experiment Station, of a State seed laboratory for the analysis of all commercial seeds, and for the purpose of seed control as defined by appropriate statutory legislation.

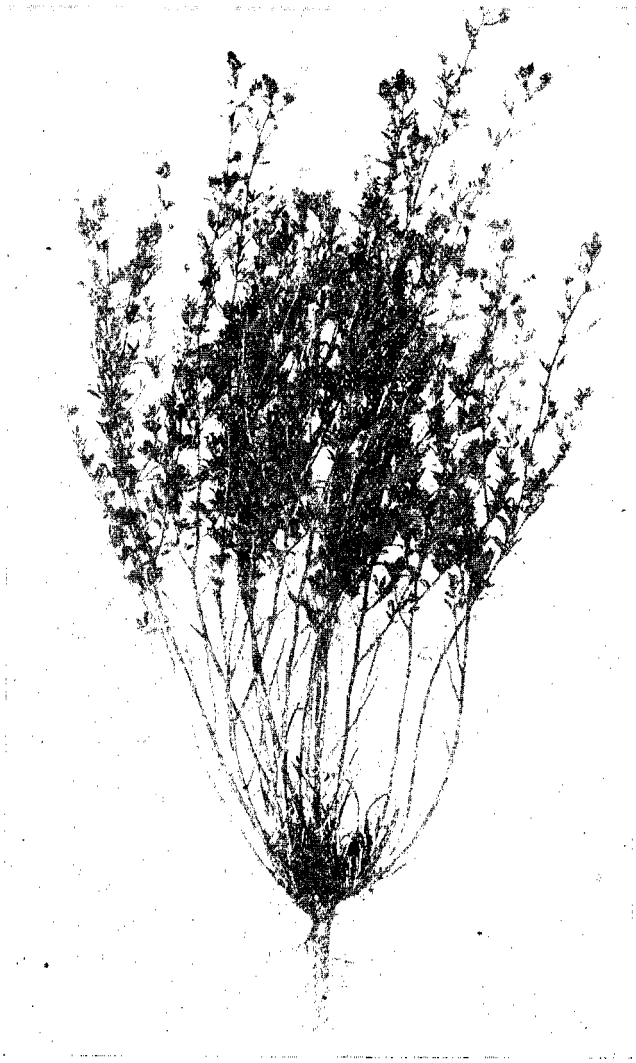

PLATE I.—Plant of Medicago sativa (alfalfa).

PLATE II.—Plant of Medicago lupulina (yellow trefoil or hop clover). A common adulterant of alfalfa. Leaflets broader and more clover-like than in alfalfa. Yellow flowers sparsely scattered in small, hop-like clusters, at tips of long flower-stems.

PLATE III.—Medicago denticulata (bur clover). An occasional adulterant of alfalfa. Leaflets broader and more wedge-shaped than in yellow trefoil. Flowers similar to those of trefoil. Pods coiled and spiny.

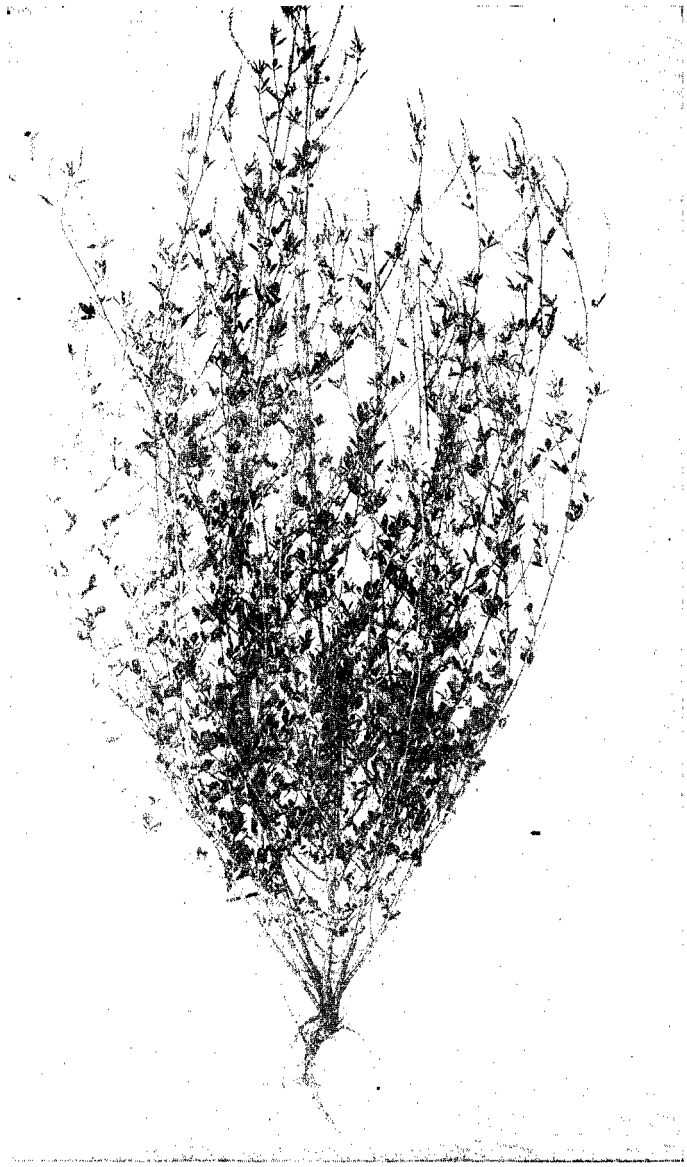

PLATE IV.—Melilotus alba (sweet clover). An occasional adulterant of alfalfa. Plant much taller than any of the species of Medicago. Flowers white, borne in rows on elongated flower-stems.

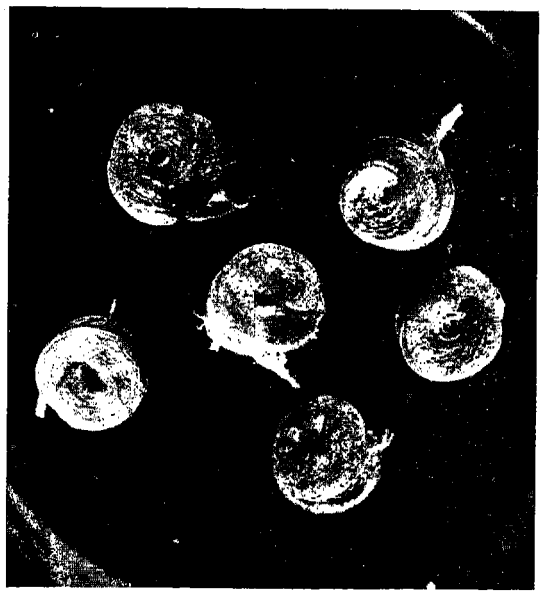

Fig. 1.—Pods of alfalfa, magnification, four diameters.

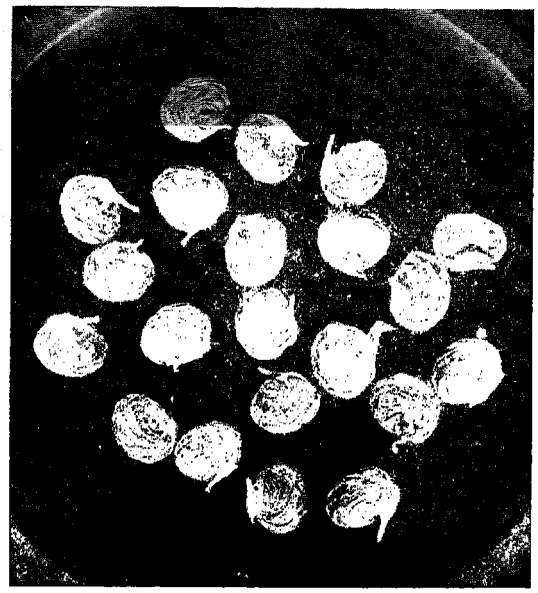

Fig. 2.—Pods of yellow trefoil, magnification, four diameters.

PLATE V.

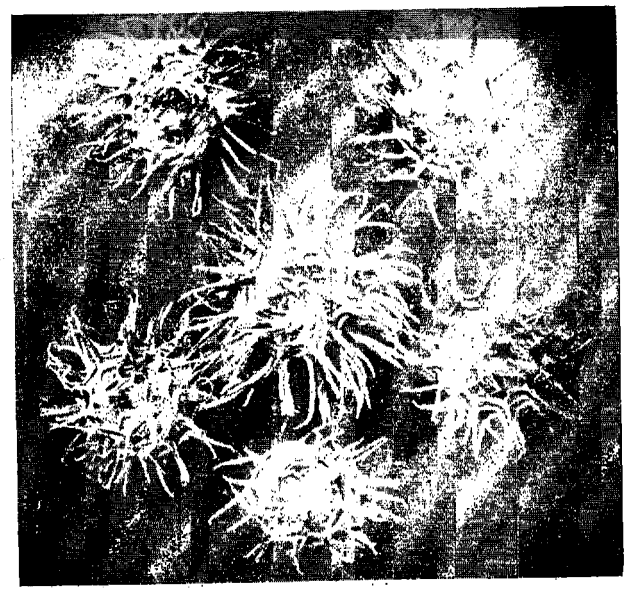

Fig. 1.—Bur clover, pods, magnification, four diameters.

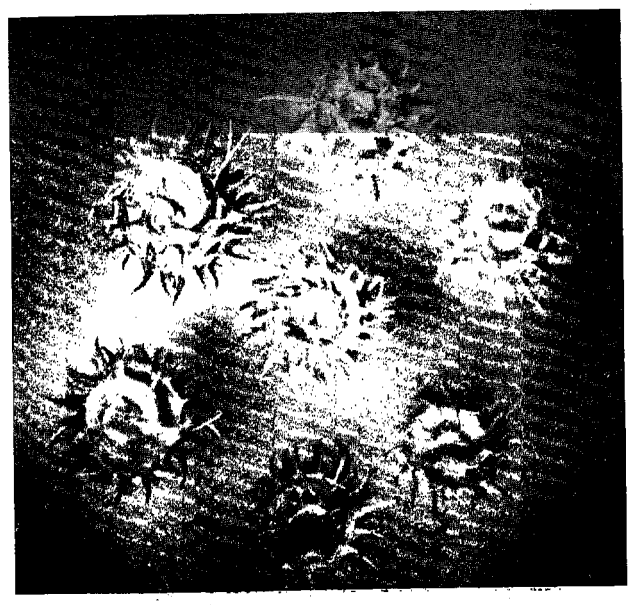

Fig. 2.—Spotted clover pods, magnification, four diameters.

PLATE VI

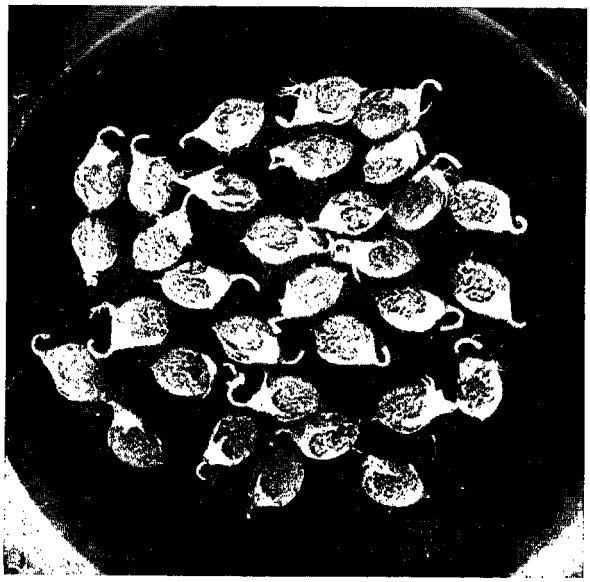

Fig. 1.—Sweet clover, pods, magnification, four diameters.

Fig. 2.—Sweet clover, pod, magnification, twelve diameters

PLATE VI

Fig. 1.—Alfalfa pod, magnification, six diameters.

Fig. 2.—Yellow trefoil, pod, magnification, twelve diameter

PLATE VIII.

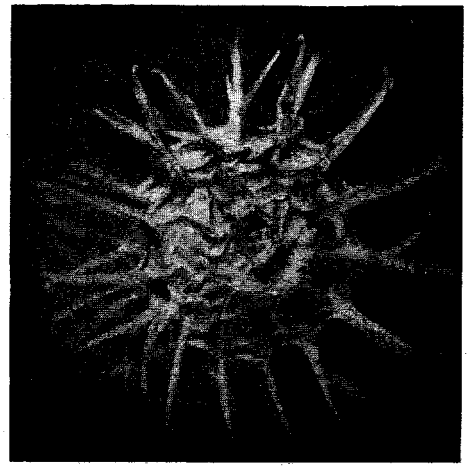

Fig. 1.—Bur clover, pod, magnification, six diameters.

Fig. 2.—Spotted clover, pod, magnification, six diameters.

PLATE IX.

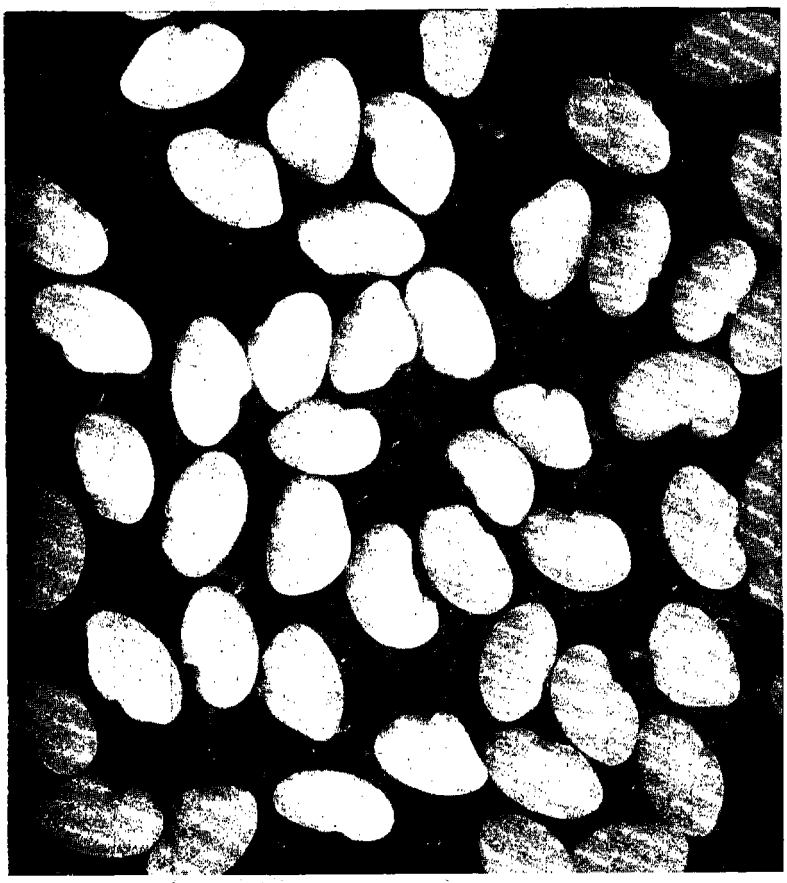

PLATE X.—Alfalfa, seeds, magnification, eight diameters. Note occasional kidney-shaped seeds, not found in yellow trefoil and sweet clover. In the majority of alfalfa seeds, observe the angular slant toward one or both tips of the seed. This does not occur in the other two species.

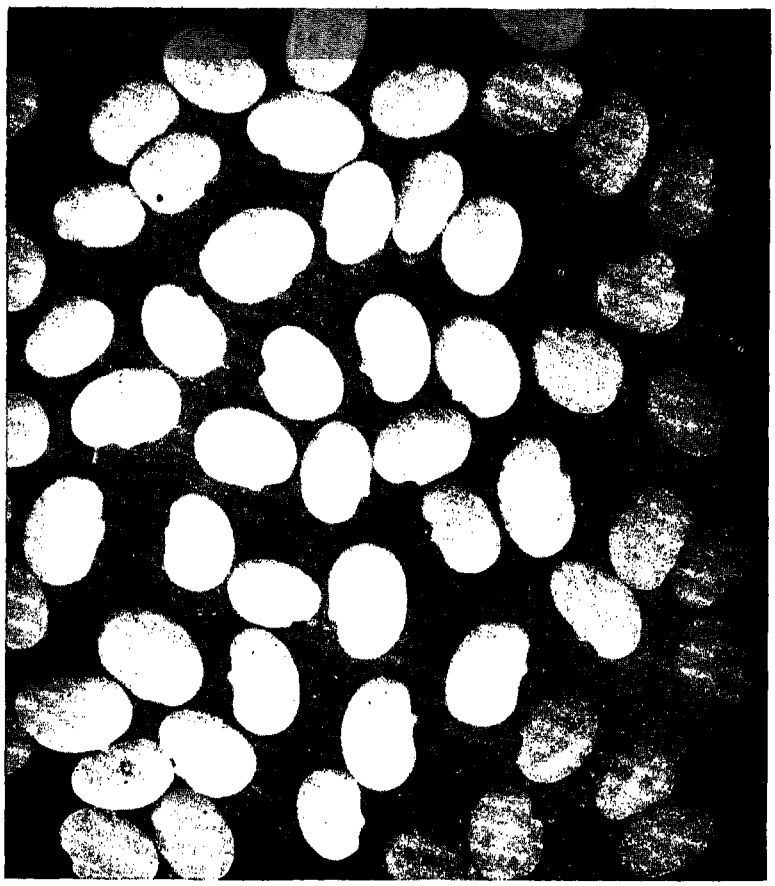

PLATE XI.—Yellow trefoil, seeds, magnification, eight diameters. Note the oblong or oblong-oval form of seeds, and the protruding "beak," characteristic of this species. Some of the seeds are with difficulty to be distinguished from alfalfa.

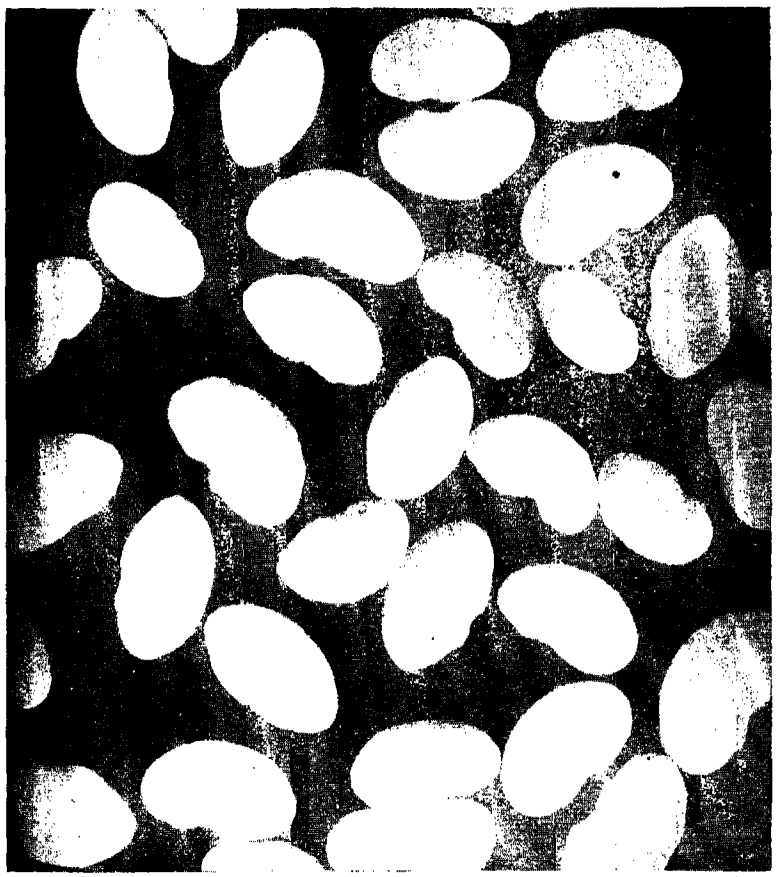

PLATE XII.—Bur clover, seeds, magnification, eight diameters. Note the greater size of most seeds as compared with alfalfa. Easily distinguishable when present in any quantity.

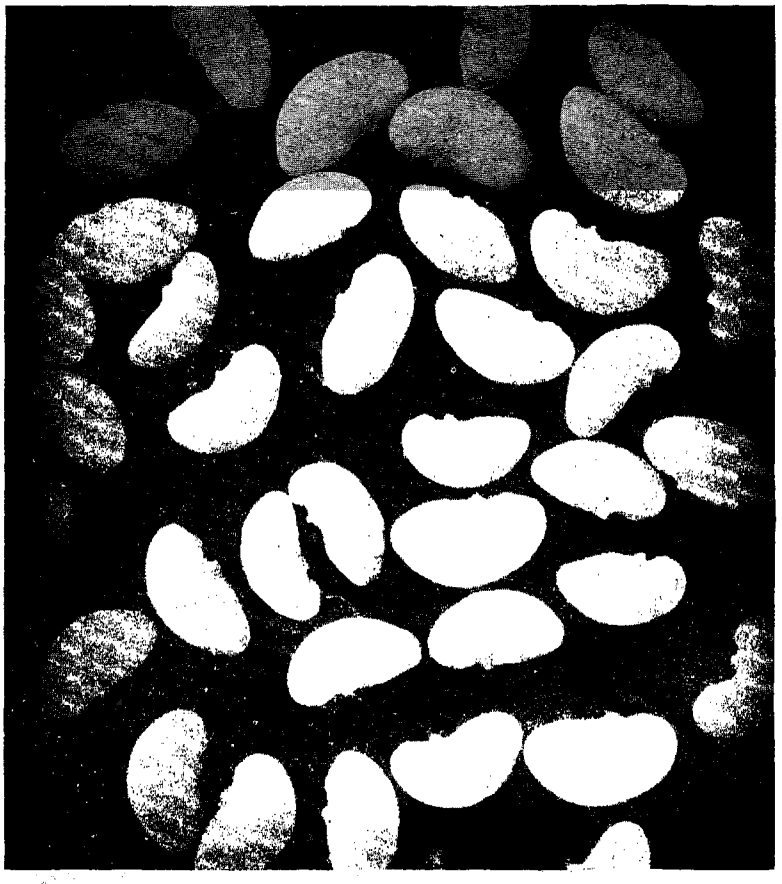

PLATE XIII.—Spotted clover, seeds magnification, eight diameters. Seeds longer than those of alfalfa, and with more pronounced "beak" than the seeds of hop clover.

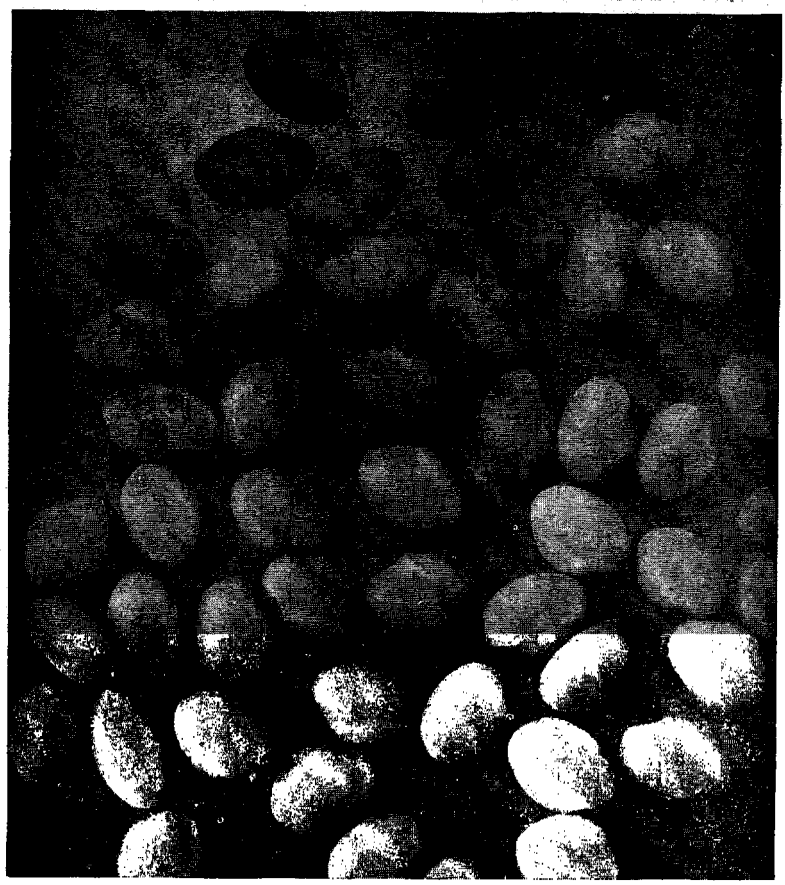

PLATE XIV.—Melilotus alba (sweet clover), magnification, eight diameters.

PLATE XV.—Medicago sativa (alfalfa), kidney-shaped type of seed, magnification, 11½ diameters.

Fig 1.—Medicago sativa (alfalfa), magnification, 11½ diameters, pointed type of seed.

Fig. 2.—Medicago sativa (alfalfa), magnification, 11½ diameters, rounded type of seed.

PLATE XVI.

Fig. 1.—Medicago denticulata, magnification, 12 diameters.

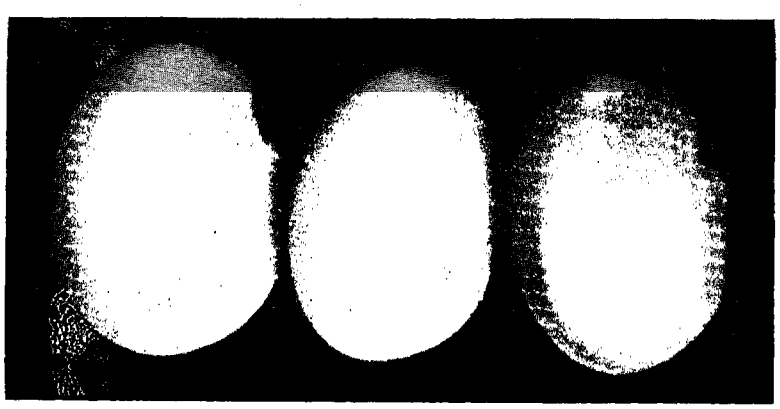

Fig. 2.—Medicago lupulina, magnification, 12 diameters.

PLATE XVII.

Fig. 1.—Medicago arabica (spotted clover), magnification, 12 diameters.

Fig. 2.—Melilotus alba (sweet clover), magnification, 12 diameters.

PLATE XVIII.

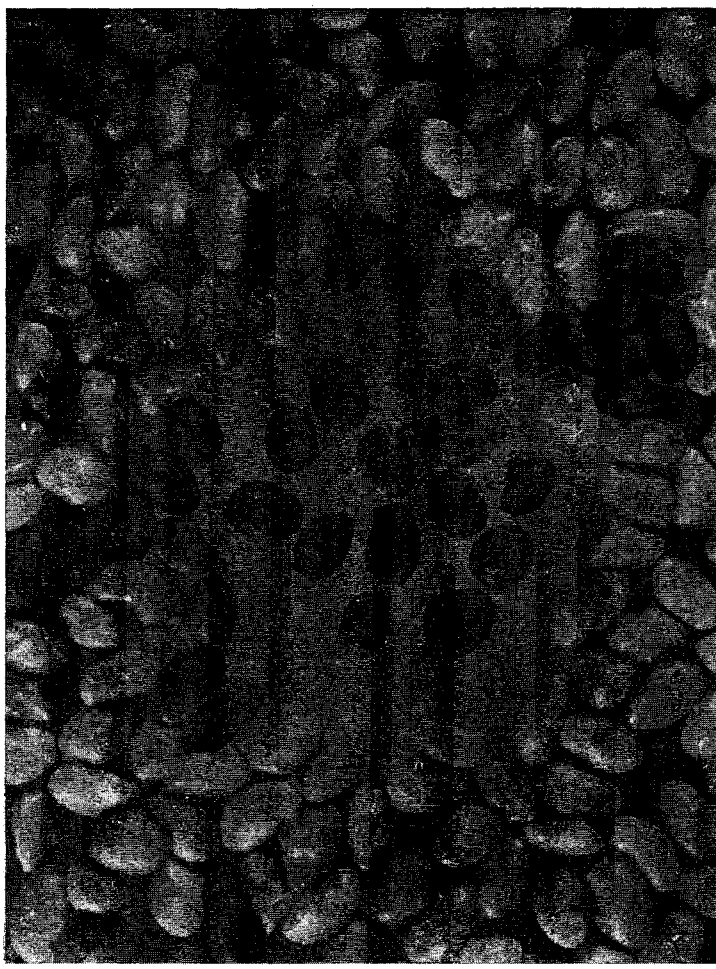

PLATE XIX. A group of yellow trefoil seeds, surrounded by seed of alfalfa. Magnification, 5 diameters.

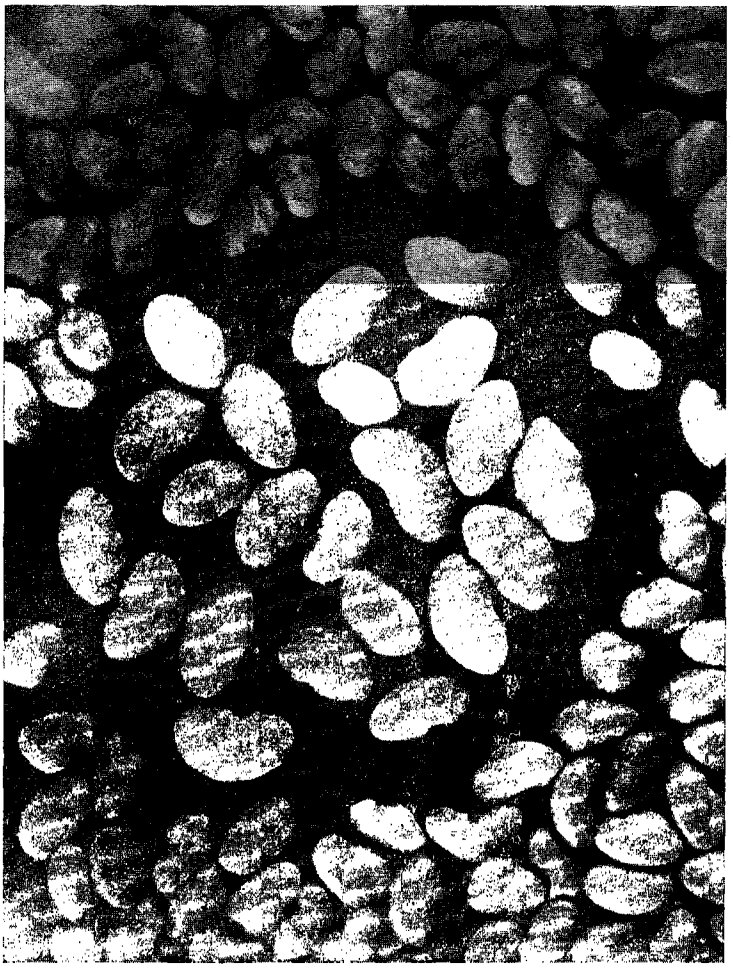

PLATE XX.—Seeds of bur clover, surrounded by alfalfa seed. Magnification 5 diameters.

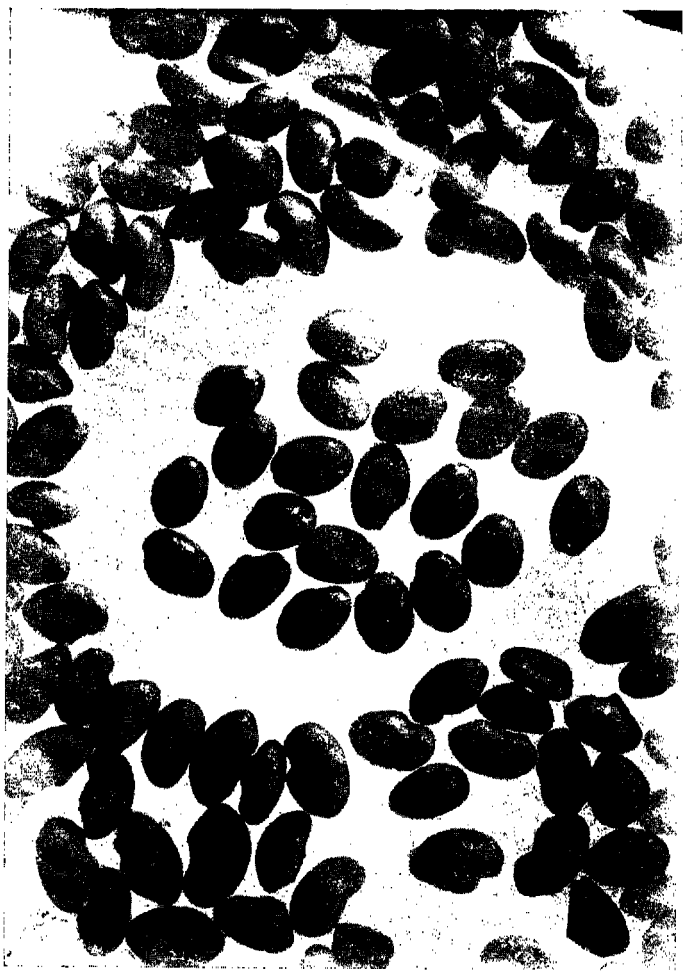

PLATE XXI.—Seeds of sweet clover, surrounded by alfalfa seed. Magnification, 5 diameters.

Fig. 1.—Yellow trefoil.

Fig. 2.—Alfalfa.

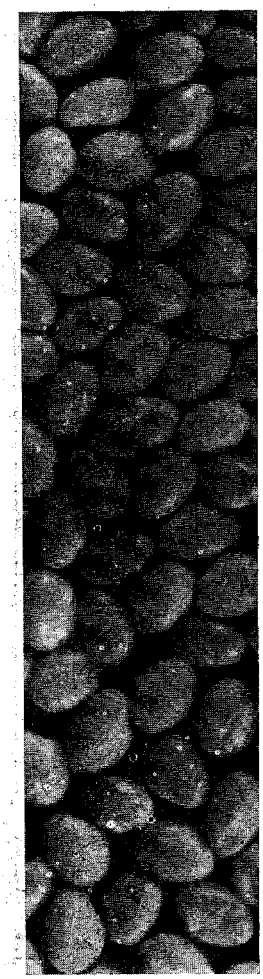

Fig. .—Sweet clover.

(All magnified five diameters).

PLATE XXII

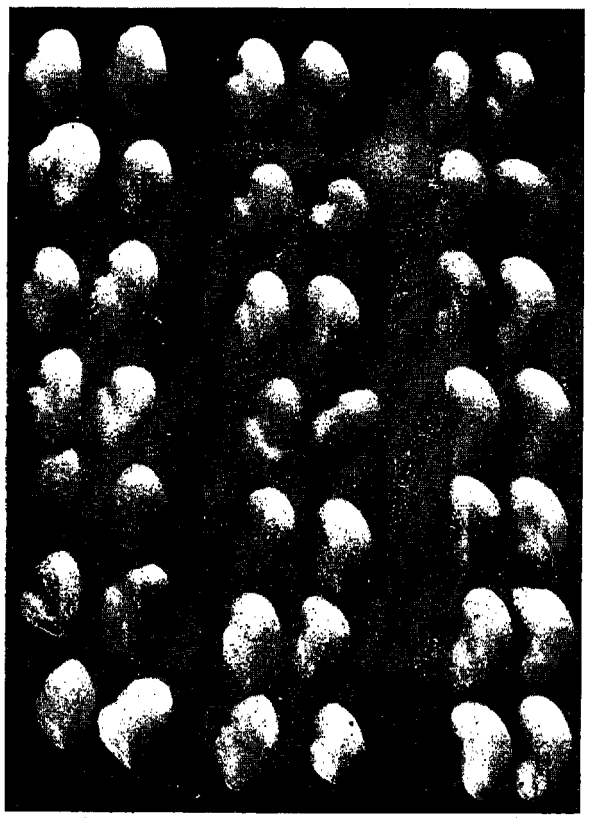

Fig. 1.--Three vertical double rows illustrating three intergrading types of alfalfa seed. The two rows to the right illustrate the kidney-shaped type, the two in the center the angular, pointed type, and the two on the left approximate more or less closely to the rounded type seen in the sweet clover, and sometimes in yellow trefoil, particularly, for example, the lowermost seed in the extreme left-hand row. Magnification, 5 diameters.

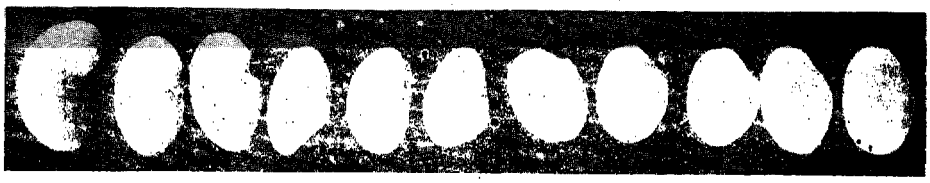

Fig. 2.—Illustrating intergrading types of seed between alfalfa and sweet clover. The six seeds to the left being alfalfa, the five to the right sweet clover. Magnification, 8 diameters.

PLATE XXIII.

PLATE XXIV.—From a photograph of good commercial alfalfa seed. Magnification, 8 diameters

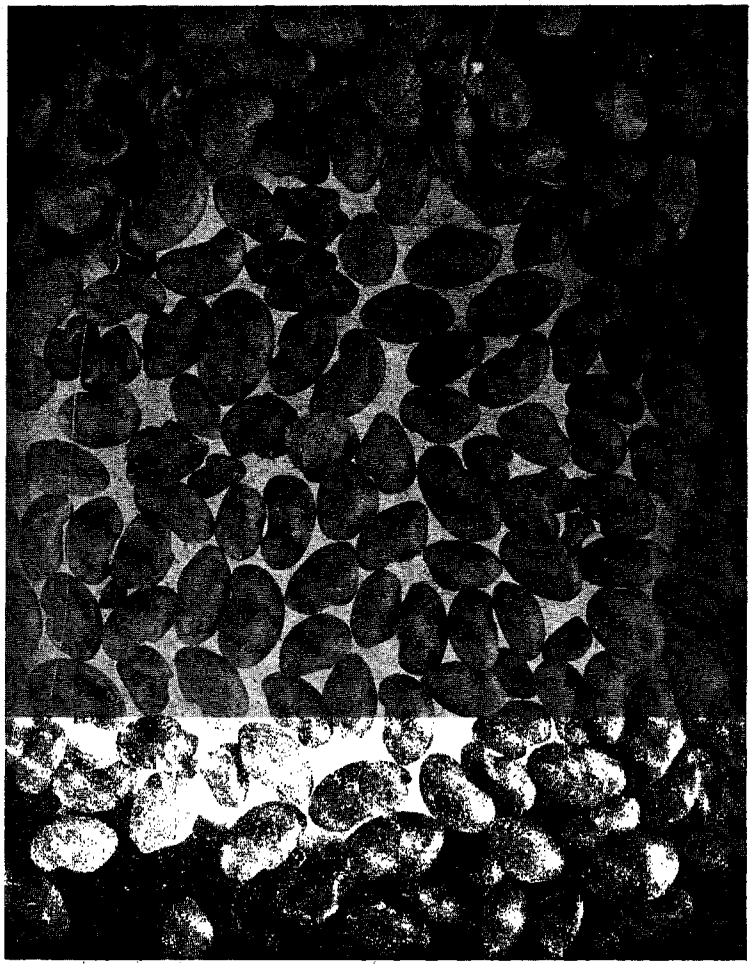

PLATE XXV.—From a sample of low-grade alfalfa seed, magnification, 5 diameters. This sample contained a large amount of dead, decayed and immature seed of alfalfa, as well as a large quantity of weed seeds (chiefly dock) and debris of various sorts.

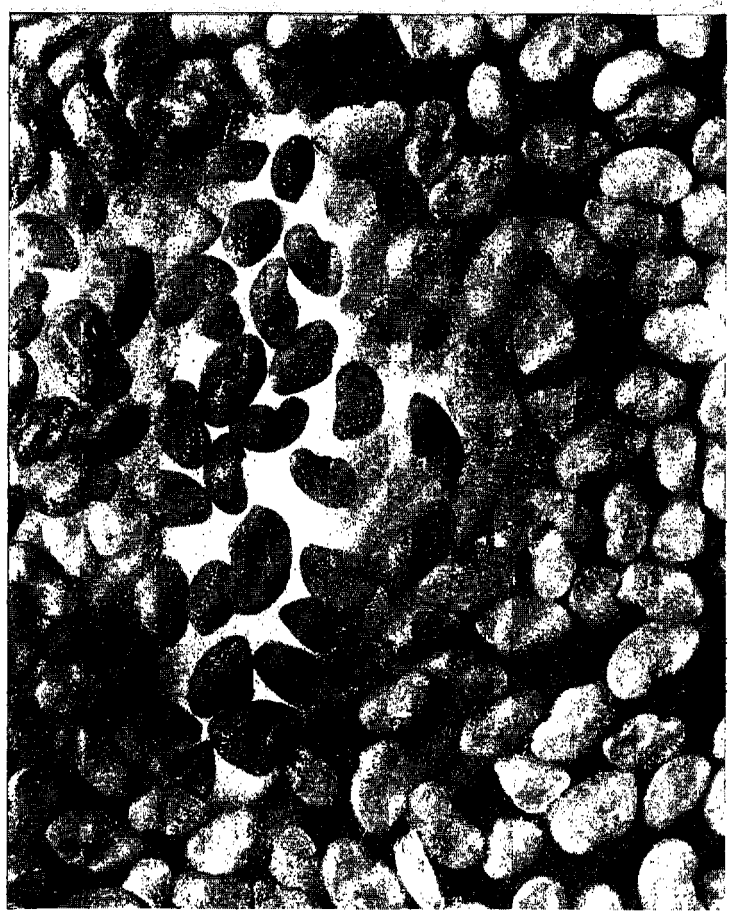

PLATE XXVI.—Dead, decayed and defective alfalfa seeds, from five grams of the sample illustrated in Plate XXV. Magnification, 5 diameters.

PLATE XXVII.—Weed seed taken from five grams of the sample of alfalfa illustrated in Plate XXV. The triangular seeds are of dock, the oval-pointed seeds are of foxtail. Magnification, 5 diameters.

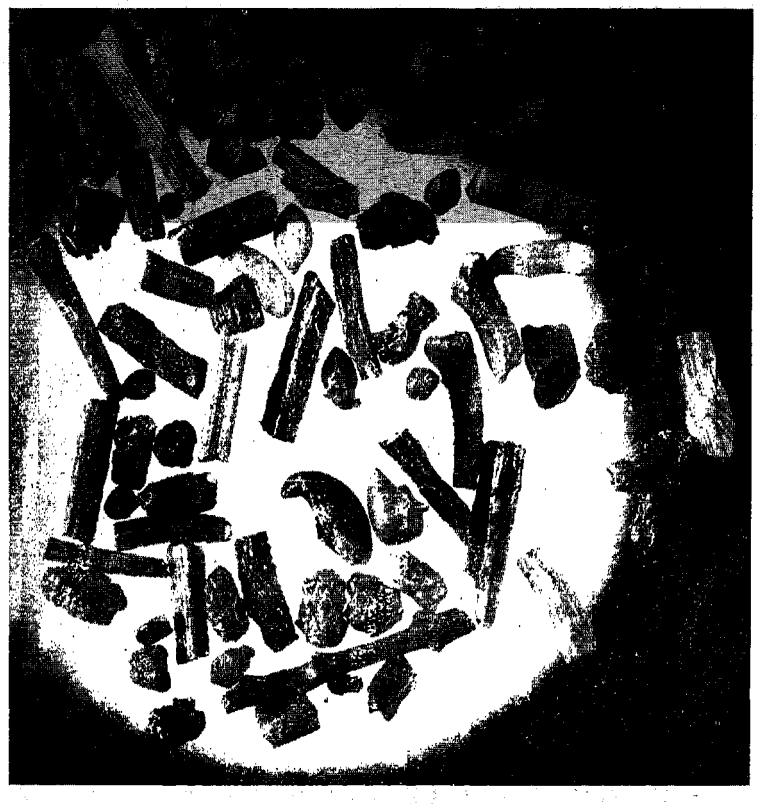

PLATE XXVIII.—Inert matter (sticks, stones, dirt, etc.), taken from five grams of the sample illustrated in Plate XV. Magnification, 5 diameters.

PLATE XXIX.—Seeds of Plantago lanceolata (Buckhorn, Ribbed plantain, English plantain or Rib-grass). The weed most constantly occurring in imported alfalfa seed. Magnification. 8 diameters.

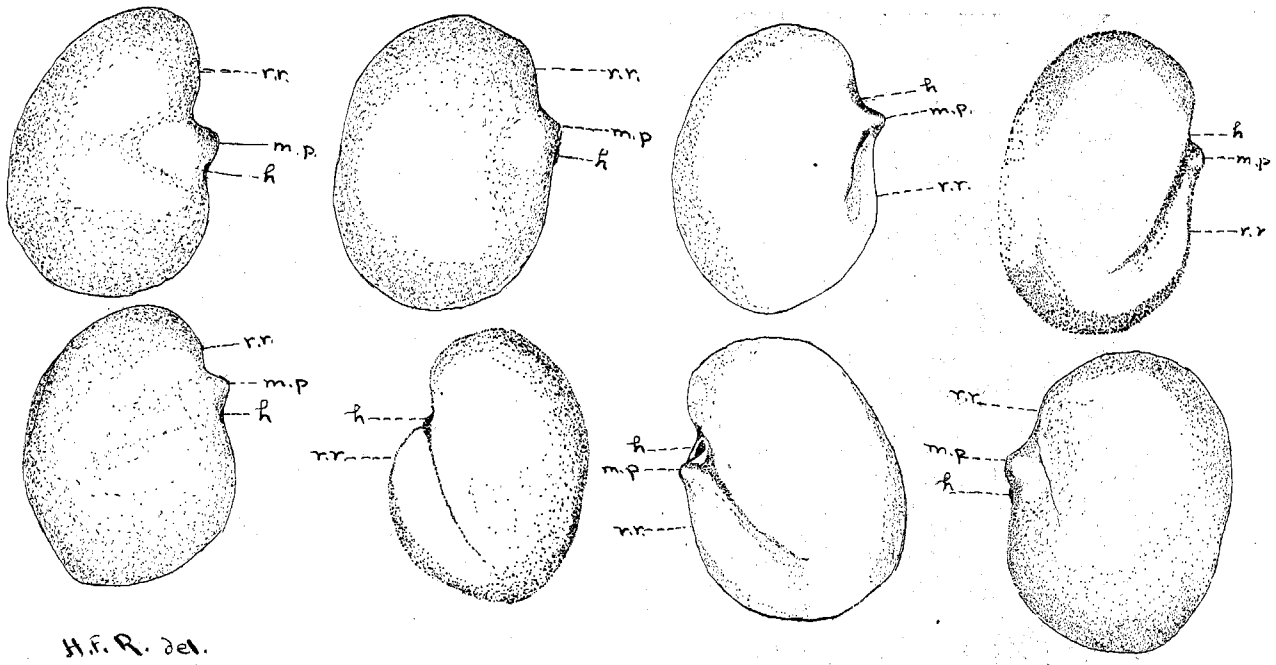

PLATE XXX—Seeds of yellow trefoil,—Medicago lupulina—, X 25 diameters. h,—hilum (the scar left at the point of attachment of the seed to the pod, after the seed has become detached; m. p.,—micropyle point (the small opening in the ovule through which the pollen tube entered to reach the egg cell, and through which, in leguminous seeds, the rootlet or radicle emerges from the seed coat on germinating. This point in yellow trefoil stands at the summit of an elevation referred to in this bulletin as the "beak," quite characteristic of most seeds of this species and not noticeable in seeds of alfalfa.) r. r.,—radicular ridge; the ridge or elevation formed by the radicle of the embryo and which is usually less prominent in trefoil than in alfalfa and sweet clover. See also Plates XXXI and XXXIII.

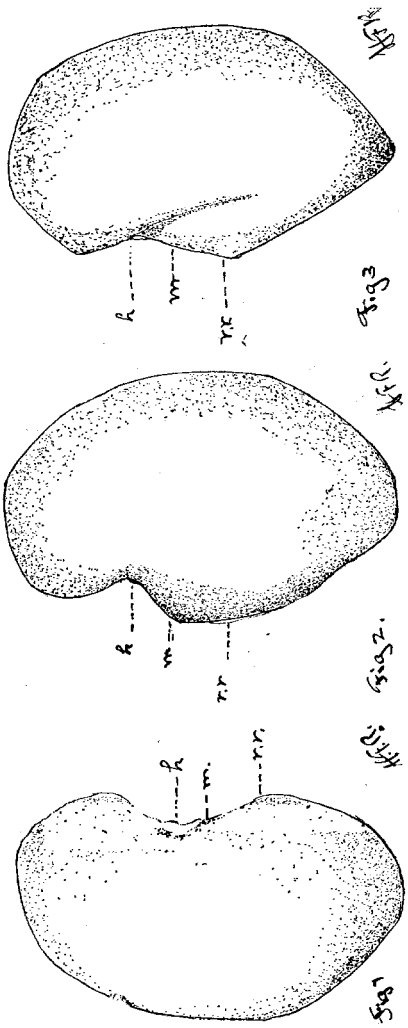

PLATE XXXI.—Seeds of alfalfa (Medicago sativa), X 25 diameters. h,—hilum; m,—micropyle; r,—radicular ridge. Note in alfalfa seeds, as compared with those of yellow trefoil in Plate XXX, the fact that the micropyle is not prominent and that the radicular ridge slopes off rapidly and sharply toward the point of the seed, not forming a swelling curve.

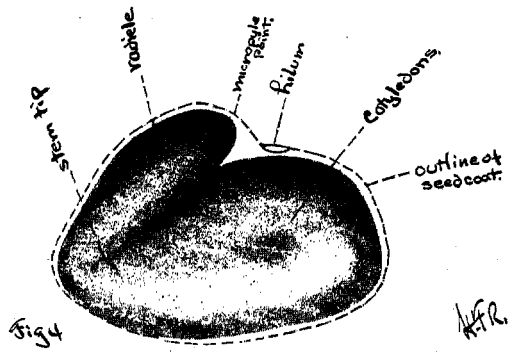

PLATE XXXII.—Sweet clover (Melilotus alba), seed showing relation of the embryo to the seed coat. X 25 diameters.

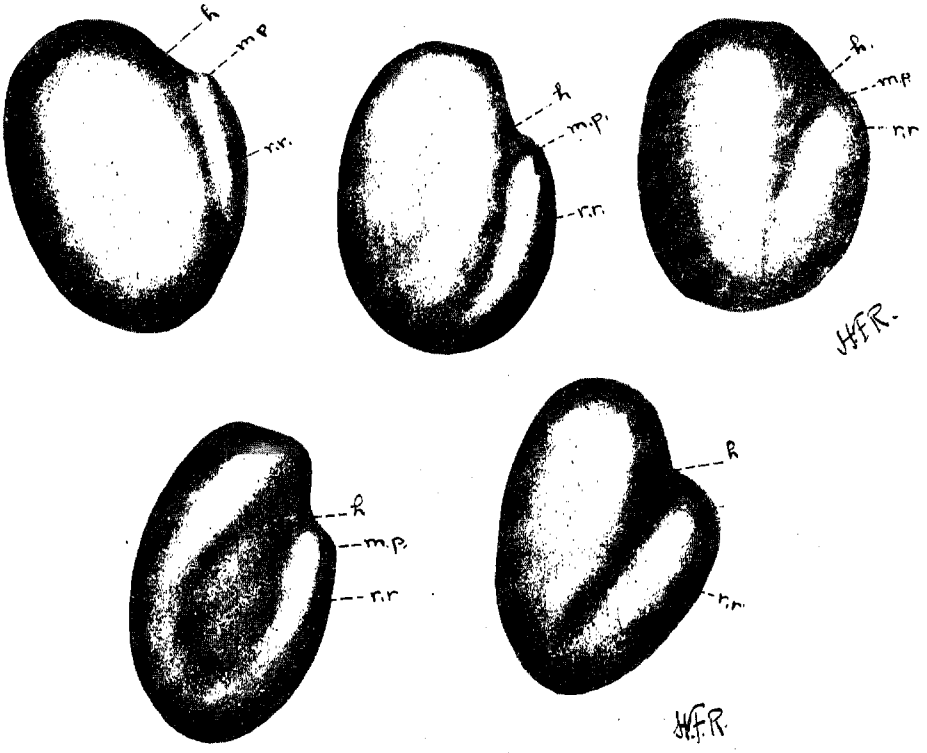

PLATE XXXIII.—Sweet clover (Melilotus alba) X 25 diameters. h.—hilum; m. p.—micropyle point; r. r.—radicular ridge. Note in sweet clover, as compared with alfalfa seeds in Plate XXXI, the location of the hilum near the end of the seed, greater elevation of the micropyle point, and the swelling rounded curve of the radicular ridge.