accidental volunteer plants, but that they were actually the product of the seed which we had sown and that evidently we had to do with either a mutation or a hybrid. Subsequent results proved the latter to be the case. In the 96 rows of this plot, eight separate cases of this sort were found. The following year seed from each of these eight beardless plants was sown in separate rows alongside that from as many sister (or more strictly speaking half sister) bearded plants. The latter reproduced true to type in every case, but the beardless seed produced a crop which gave Mendelian segregation into bearded and non-bearded forms, the beardless character being the dominant.

Further propagation in pure lines has given in two subsequent generations the expected Mendelian behavior, the bearded segregates breeding true to this character while a proportion of the beardless split up.

Other characters segregating independently, such as color, length of spike, hairiness of glumes, have also been noticed in these strains.

From all of this evidence we are brought to the conclusion that the beardless plants found in our "pure" strains of Turkey Red were F_1 hybrids, resulting from the occasional accidental crossing of a flower in the mother plants.

These observations taken together with others on record lead us to conclude further that such natural crossing may occur more frequently than has been generally supposed, and that this may be a serious factor with which we have to deal in breeding operations and in the maintenance of the purity of varieties.

BREEDING ALFALFA AS A DRY LAND CROP

A. C. DILLMAN

Washington, D. C.

Drought resistance of alfalfa.—The importance of alfalfa as a forage crop has seemed to warrant all the efforts that have been made toward its improvement. The excellent feeding value of the forage, whether used as pasture or as hay, and for all classes of farm animals from "the great American hen" to the noble draft-horse, makes the crop of especial value whether grown under humid conditions or as a dry land crop.

The use of alfalfa, too, for soil improvement both on account of the nitrogen added to the soil and because of what we may term the sub-soiling effect of the deep roots, makes the crop valuable in

any system of crop rotation. It is rather exacting in its requirement for lime, but fortunately this element is found generally in the soils where dry farming is practiced.

The crop is of course especially adapted to use under irrigation because of its quick recovery after cutting and because of its long season of growth which allows three or more crops to be harvested each year. There are also certain favored localities in the dry land area in which ground water is found within a few feet of the surface where alfalfa can be grown to the same advantage as under irrigation. In these areas the crop can make use of a level of ground water which would be out of reach of shallower rooted crops. These are in brief some of the advantages of the crop in general. It may be well now to consider both its disadvantages and advantages as a dry land crop.

One of the faults of alfalfa as a dry land crop is its habit of continuous and long season growth, the very factor which makes it valuable under irrigation. Under dry land conditions this factor is a disadvantage for the reason that it is not possible to store a great amount of moisture in the soil of an alfalfa field to aid the crop in passing a dry period. The continuous growth causes it to use up the moisture as fast as it is available, and the result is, that in a season of limited rainfall, there is not enough moisture at any one time to produce a profitable crop. While, if it were possible to store in the soil the rainfall for a part of the season, the accumulated moisture would be sufficient to produce a normal yield. In the case of an annual forage plant, sorghum or millet for example, the growth is made in three months of the year, while the soil may be handled during the remainder of the year in such a manner as to conserve the rain that falls. In this respect the annual crop is no doubt better adapted to dry land conditions than is alfalfa.

In selecting a strain of alfalfa, or of any forage crop which will be at the same time productive and adapted to dry land conditions, we encounter the difficulty that by increasing the amount of vegetative growth, we increase the amount of transpiration and of water used. That is, large vegetative growth, which is the chief requirement of a forage crop, is opposed to economy in the use of water. If the required product were seed alone, as in the crops with which the grain breeder is concerned, then the problem would be easier. I have observed numerous individual plants and several progeny rows of alfalfa that were excellent in seed production but were seriously lacking in forage production. Such a type of plant, with few stems and leaves, may no doubt be economical in its use of water,

and may be efficient in seed production, but is worthless from the forage standpoint. It is necessary I believe to keep in mind that forage production is the first requisite, even though other types may show greater water economy.

In regard to the actual drought resistance of alfalfa, it is necessary to distinguish between the behavior of the green portion of the plant and the plant as a whole. It is a matter of common observation that when the fully developed leaves and stems wilt badly, due to drought, their growth is permanently checked and they will not revive so as to continue growth with return of favorable conditions, but instead the plant will start out new shoots from the crown. In this respect alfalfa is very different from sorghum which is able to cease growth during a dry period of considerable duration and to revive with normal growth on the return of favorable conditions. This lack of drought endurance of the growing stems of alfalfa may appear a fault, but in reality is of great advantage to the plant in stopping transpiration before the soil moisture is entirely exhausted. In this way vitality is retained in the crown and roots of the plant with which to develop new stems when favorable conditions recur. The dormant condition which alfalfa enters during a period of drought is not unlike the dormant condition during winter; the leafy stems wilt, but the drought endurance, like the cold endurance, is found in the roots and crown of the plant.

The remarkable drought endurance of the plant was proved during the past season at the Bellefourche, South Dakota, Experiment Station where the season was extremely dry. There was not enough rain at any time before August to germinate the grains seeded in March or start the growth of alfalfa and of the native grasses. The alfalfa remained dormant during this period which included the hot summer months, but started growth when rain fell in the latter part of August. Only a small percentage of the plants were killed outright by the drought. Alfalfa proved one of the most drought resistant of the cultivated perennial crops and stood the drought nearly as well as the native grasses—buffalo grass and western wheat grass.

In breeding alfalfa as a dry land crop it is necessary to keep in mind in what respect drought resistance can be obtained. It was formerly believed that plants differed widely in their ability to draw upon the soil moisture. It was thought that by virtue of a stronger "root pull" some plants could continue to absorb moisture and grow in a soil where other plants would wilt and die from lack of moisture.

Recent investigations[a] have shown that plants differ but slightly in this respect.

In selecting plants for drought resistance then, we must look for some other cause to account for the superior growth of one plant over that of its neighbors. This superior growth may be due either to a greater root development or to a greater economy in the use of water, that is, a less volume of water used per unit of dry matter produced. All investigators have found a vast difference in the water requirement of different cultivated crops and this suggests the probability that there are differences in the water requirement of varieties and strains of each crop. This is indicated, too, by the experience of investigators of grain crops who have found some varieties yielding much better under conditions of drought than others. The Nebraska Station[b] has found that a narrow leaf strain of corn yielded considerably more than a broad leaf strain both selected from the same variety, Hogue's yellow dent. And so in breeding alfalfa as a dry land crop we should seek plants having a low "water requirement." In field work a comparative test of the water requirement can be obtained by the method of testing selections in progeny rows, provided the soil conditions are uniform. The weight of dry matter produced under conditions of limited moisture supply becomes a measure of the efficiency of the plant in its use of water.

Breeding methods employed.—The breeding methods used fn this work are not new in principle, but may be worth describing briefly.

At the beginning of the work all strains of alfalfa which could be obtained from various sources in this country and Europe were tested for hardiness and forage production. This test eliminated a large number of strains, chiefly on account of lack of hardiness, and proved the decided superiority of the four or five strains which were retained as foundation stocks.

These hardiest strains were then planted in selection rows where the plants were allowed to develop normally without crowding, so that the individual characters of each plant could be studied. It is convenient in keeping notes to have the plants at definite distances apart, as one would check-row corn in hills, so that the plants are in line in both directions. In this way one can designate each plant by number from the position it occupies in the row, and thus avoid the use of stakes which are easily lost or destroyed in cultivation.

[a] Briggs, Lyman J. and Shantz, H. L., The Wilting Coefficient of Different Plants and Its Indirect Determination. Bulletin 230, Bur. Pl. Ind., U. S. Dept. Agri.

[b] See Twenty-fourth Annual Report, Neb. Exp. Sta., p. ix.

If a plant is missing in the row the order of numbering is not changed, each plant in the row being permanently designated by the position it actually occupies.

From the selection rows numerous individual plants which combined the best forage type with a tendency toward good seed production were selected, and the following year seed from these was planted in progeny rows (fig. 1) in the same manner as the selection rows were planted. A detailed description is kept of each individual

FIG. 1. PROGENY ROWS OF ALFALFA.

From seed of individual plants which represent the fourth generation of selection from Grimm alfalfa. Bellefourche Experiment Farm, June 21, 1911.

selected as a mother plant, and in most cases a photograph is taken of the mature plant (fig. 2). We use a score card with appropriate headings for taking notes, and complete the description by writing out in full such data as are not covered by the headings. These cards are bound into a note-book for use in the field, but are perforated at the binding so as to be torn out and filed in a convenient manner for reference. The notes include: (1) The type of plant—whether

erect, spreading, or decumbent; (2) The character of the stems—whether coarse and woody, or fine and succulent; (3) The amount and character of branching including the number and length of internodes; (4) The relative leafiness together with the shape and size of the leaves; (5) The flower color; and (6) The seed production

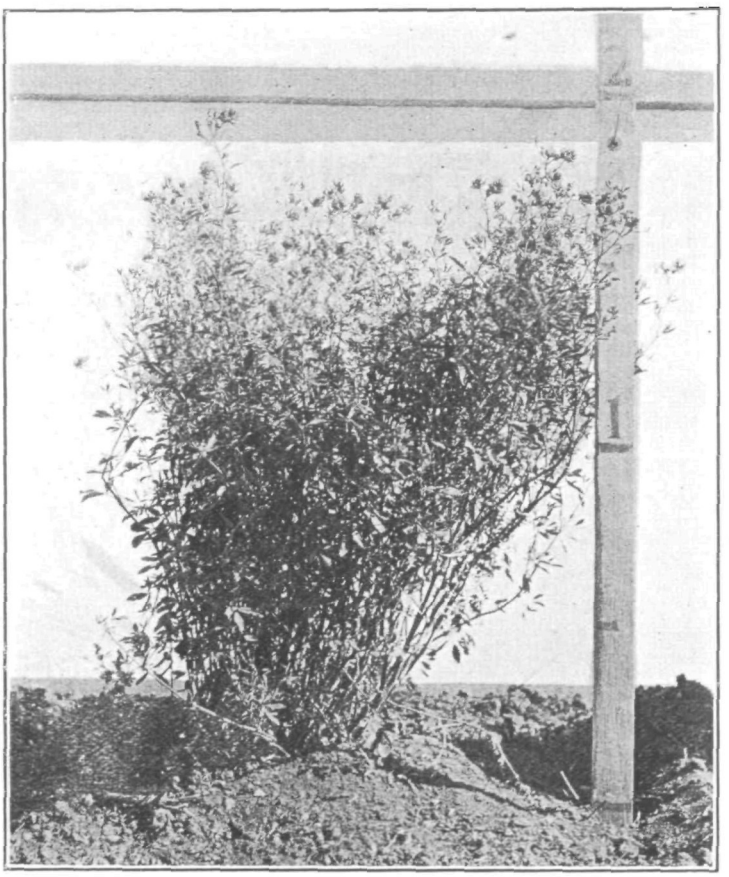

FIG. 2. A DESIRABLE TYPE OF ALFALFA PLANT.
Erect, with numerous fine stems, leaves abundant, and seed production good.

as estimated from the number of pods and the number of seeds per pod. After harvest the yield of the plant is entered—including total dry weight, weight of seed, and percentage of seed to total weight. This last record, percentage of seed to total weight, is a convenient index of the relative seed producing ability of the plant.

The plants which are tentatively selected at the period of blossoming are carefully compared at the time the seed is ripe, and only those which show combined excellence in forage type and seed production are finally chosen. These are cut separately and each is placed in a cloth bag to dry.

Crop,		*A. & D. No.*	
Date,	*, 191*	*Station,*	
LOCATION: Plot	Row		Plant No.
DATE: Planted		Growth starts	
First bloom		Full bloom	
Ripe		Harvested	
Type of plant			
Height		Stools, number of	
Internodes, number of		Length	
Leaves, number of	Length		Width
Pods, number of		Seeds per pod	
Drought resistance			
Growth after harvest, vigor			Height
YIELD:			
Weight of plant		Seed	Straw
Percentage of seed			
Number of seeds per gram weight			

FIG. 3. SCORE CARD USED FOR INDIVIDUAL PLANT SELECTIONS OF ALFALFA.

In order to compare the value of the progeny rows careful notes are taken on each plant in the row (see fig. 4) at the beginning of the blossoming period, since the forage type of the plant is best judged at this time. After these notes are taken all the inferior plants, as well as all that are divergent from the type of the row, are removed in order to prevent cross pollination from these undesirable plants. Later in the season, when the seed is ripe, the best

individual plants are selected and handled as described, while the remaining plants in each row are harvested in bulk, dried in shocks, weighed and threshed. Since a record is kept of the number of plants harvested, an accurate estimate can be made of the producing power of each progeny row.

The yields of several progeny rows grown at the Bellefourche Station, S. D., in 1909 are shown in table 1.

TABLE 1.—*Showing yields of progeny rows of alfalfa grown at Bellefourche, S. D., in 1909. Variety E is Grimm alfalfa, Variety F is Turkestan.*

Variety and progeny number.	Average dry weight per plant.	Average seed yield per plant.	Percentage of seed to total weight.
	grams.	*grams.*	
E1	171	27	16
E2	171	18	10.5
E4	189	33	17.5
E5	144	23	16
E6	192	32	16.5
E7	150	25	16.5
E9	150	22	14.5
E10	138	22	16
E12	150	21	14
E13	138	19	14
E15	180	27	15
E17	138	20	14.5
E18	165	28	17
E19	180	33	18.5
Average of strain *E*.....	161	25	15.5
F1	144	18	12.5
F2	150	20	13.5
F3	150	19	12.5
F5	135	14	10.5
F6	132	15	11.5
F7	134	22	16.5
F8	192	28	14.5
F9	144	17	12
F11	144	20	14
F12	180	30	16.5
Average of strain *F*.....	150	20	13.4

The average of all progeny rows in strain *E*, representing 600 plants, was 161 grams dry weight and 25 grams of seed per plant.

In strain *F*, 354 plants averaged 150 grams dry weight, and 20 grams of seed.

It will be seen that six progeny rows in strain *E* produced forage and seed above this average of the entire strain. These were E1,

E4, E6, E15, E18 and E19. And in strain *F* two progeny rows (F8 and F12) yielded above the average of the strain.

Under the conditions where these progenies were grown, where lack of moisture was the chief limiting factor in crop production, these results should in a measure indicate the relative efficiency in

Alfalfa—Individual Notes. *A. & D. No.*

Date, , *191* *Station,*

Plant number	1	2	3	4	5	6	7	8	9	0
STAND: Sept. , 191										
May , 191										
DATE: Growth starts										
First bloom										
Ripe										
Drought resistance										
Type of plant										
Branching										
Leafiness										
Color of blossom										
Seed production										
Plants discarded										
Plants selected										

FIG. 4. SCORE CARD FOR ALL THE PLANTS IN A PROGENY ROW.
By inserting the tens figure before the 1, the series becomes 11 to 20, or 21 to 30, etc., as desired.

the use of water of the progenies tested. Seed from the best progeny rows has been planted in a duplicate series of one-tenth acre plots in comparison with the original stocks of Grimm and Turkestan alfalfa and will be tested further in order to determine what progress has been made.

There is at least one fault, however, in the ordinary row method of testing progenies, and that is, there is no check made on the root development of the different selections. So that a vigorous, early developing selection may extend its roots far into the area that belongs to the slower growing progenies at each side, and thus draw upon a much greater volume of soil moisture than its neighbors (fig. 5). To avoid this condition we plan in future work to plant

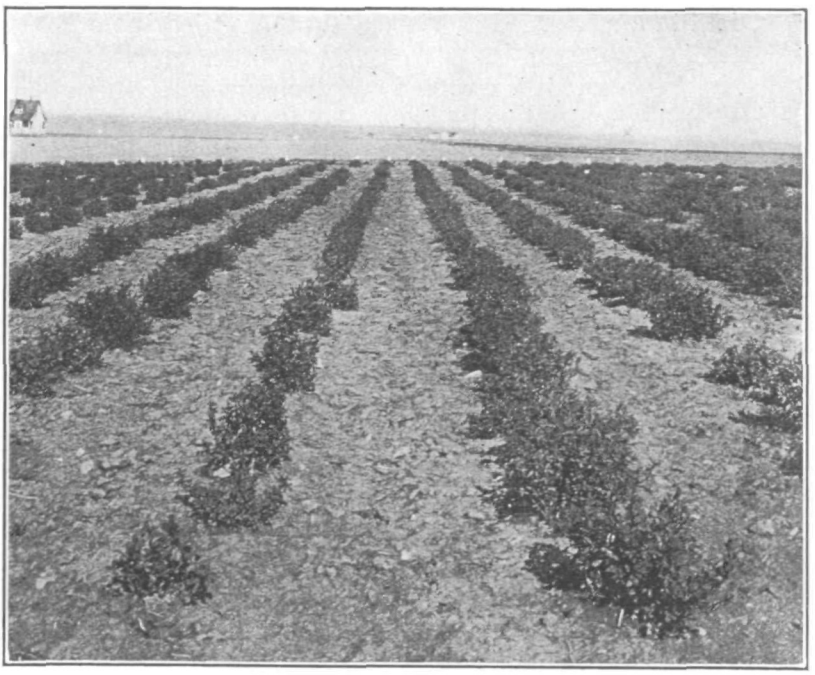

FIG. 5. THE ROW AT RIGHT OF CENTER HAS AN ADVANTAGE OVER THE ROW AT LEFT IN SECURING SOIL MOISTURE BECAUSE OF ITS GREATER VIGOR.

By planting three adjacent rows of each selection, the middle row can be grown in competition with plants of its own kind.

each progeny in three rows side by side, and then consider only the middle row in our estimates of yield, uniformity, etc. In this way each middle row is put in competition with plants of its own kind, and any superiority that one progeny may show can be attributed to real efficiency in that progeny, rather than to any advantage in the circumstances of growth.