Several of them were badly attacked by rust, much more so indeed than any of our own selections. No definite conclusions can be drawn from this one season's tests. It points, however, to the possibility that timothies will have to be selected for rather narrowly limited regions. It does not in any sense mean that the Cornell selections are inferior in themselves to their own selections, as their behavior at Arlington was certainly far below the behavior of the same varieties at Cornell. The Hopkins timothies sent to Cornell in 1906 have shown similar inferiority for conditions there. Gilmore reports that improved strains have been received from Washington. The early strain compared favorably with the early strain at Cornell, but the vigor and the pasture strains were decidedly inferior.

USE OF VEGETATIVE METHODS IN PROPAGATING.

(15) To what extent do you use vegetative methods in propagating your selections?

Webber believes that it is only valuable in extending stock of the individual to test its value and increase seed for planting larger plots. Fraser likewise believes it economical in the early history of the selection. Gilmore would use the method to secure as large an amount of seed as possible from an individual or strain of individuals. Bull has used the vegetative method in the original selection of individual plants for the purpose of obtaining a general supply of seed from these and also studying the variation therein. Allard has no doubt that the breeder can by stool division multiply and preserve promising types almost indefinitely, yet his own observations lead him to believe that a type even when thus multiplied will retain its individuality with greatly varying degree under the influence of different environmental factors.

The following paper is submitted by H. A. Allard and is offered as part of the Committee's report:

SOME PRELIMINARY OBSERVATIONS CONCERNING THE IMPROVEMENT OF TIMOTHY.

By H. A. ALLARD, *Washington, D. C.*

The study and breeding of timothy may be taken up with two very different purposes in view. One may be a problem mainly for the scientist, in an exhaustive investigation of variability, etc. The second has to do with a rapid improvement of the plant from the point of view of those qualities which make it most useful to the agriculturist. Where extensively grown, it is not probable that timothy will soon be replaced by another grass quite as palatable and nutritious, and as well adapted to the conditions which it meets throughout its range. Hence the question is one of timothy improvement itself, in such a way as to increase useful qualities already recognized and to develop any new ones that will meet the needs of the practical grower.

The plan of procedure may be very different with different breeders, and all may have their points of merit. Broadly considered, three main methods may be followed:

- (1) The introduction of superior foreign sorts.
- (2) Hybridization of varieties and species to unite desirable characters and to induce new ones.
- (3) To investigate the types or elementary species of our native timothy as a basis for obtaining uniform and improved strains adapted to special purposes.

It is doubtful if much gain can be made by the first method. The second is apt to be a complicated and hazardous one, but the last method can with certainty be made a direct, sure, and profitable one.

Throughout its range, by roadsides and in fields, types can be obtained which will furnish every degree of variability toward and away from usefulness, in the specific characters. Timothy readily escapes cultivation, and frequently makes a voluntary growth by the roadside, the equal of any in the most carefully tilled field. With this amount of variability at hand, in our native acclimated forms, it seems hardly necessary to look away from home for material as a basis for improvement.

In the improvement of timothy from the standpoint of selection and breeding, two very essential steps must be considered. In the one case every phase of usefulness of the crop must be thoroughly understood from the point of view of the practical grower. In the other case the botanical characters and correlations of every feature of the plant must be investigated. Some of the objects to be considered in the development of uniform strains and varieties are, to obtain: (1) Early productive varieties which will mature with red clover, thereby increasing the feeding value of this kind of hay; (2) early, medium and late varieties which will mature at successively later periods, thus allowing the harvesting of the crop to the best advantage, as, where a large acreage is grown to the ordinary sorts, the entire crop must be harvested at once, so that much of the grass overripens and deteriorates before it can be harvested; (3) more productive varieties; (4) leafy, stout-stemmed sorts which will better resist lodging under optimum conditions of growth and during periods of rain and wind; (5) varieties with vigorous stooling habits; (6) long-lived varieties for pasturage, etc.; (7) improved varieties adapted to local soil and climatic conditions.

My own experience with timothy has been limited almost entirely to growing and handling the crop under the best New England conditions. Unfortunately, from the point of view of real breeding, I have been able to make little more than preliminary observations. A considerable number of careful selections were made everywhere, by the roadside, in fields, etc., of types found around Washington, and also of promising types found in various portions of Connecticut and Massachusetts. These were carefully saved and notes were

made upon them, but frequent, long interruptions by other work made it quite impossible to get satisfactory, consecutive results. Nevertheless, these observations made here and there have been more or less suggestive, and have emphasized the importance of carefully considering the botanical characters of the plant and their relation to environmental factors.

Timothy is probably almost wholly open-fertilized, yet at the outset an important step is to determine if self-fertilization can be artificially effected; if so, this would make the work of fixing desirable types far more certain. Concerning this point, no conclusions seem yet to have been reached.

In every locality throughout its range, the apparently distinct types are almost numberless. These may be early or late types, tall or dwarfed, long or short-spiked, long or short-leaved, and so on down to every detail of the structure of the plant. Timothy propagates readily, not only by seed, but also by stooling, which is an interesting and well-defined method of vegetative multiplication. A single individual plant in a few seasons gives rise to a compact, closely related community of similar members. This similarity of individuals in the same stool, even to minute characters of spike, leaf, and stem is most striking. There is no doubt but that the breeder can, by stool division, multiply and preserve promising types almost indefinitely. Yet my own observations lead me to believe that a type even when thus multiplied will retain its individuality with greatly varying degree under the influence of different environmental factors.

Seed propagation, on the other hand, at least where promiscuous crossing has taken place, often failed to preserve promising parental characters. In 1906, I found a single timothy spike by the roadside in the Connecticut Valley, just 12 inches long. I saved the seed in order to test the progeny of this remarkable plant. The seeds were sown in Central Massachusetts, at a locality where quite different soil conditions existed, and under rather adverse growth conditions. The progeny without exception were all greatly dwarfed, with heads little over an inch in length. A number of progeny of other types were studied under the same conditions, but the different specific parental characters were quite wanting.

I am led to believe more and more forcibly that environmental factors have much to do with accentuating and preserving certain types. This seems true of bulbous and fibrous rooted forms, and especially of those forms in which the spikes have become markedly branched or compound. This last spike character appears closely associated with an exuberant growth vigor induced by optimum conditions of food supply, etc. So long as the conditions prevail which induce the character to become evident, it will persist in every member of the stool. However, I found, by transplanting a number of these individuals to greenhouse conditions, that the panicked character became latent, and the normal form of spike was induced. This character, as well as others no doubt, is latent in varying de-

greens with different individuals side by side. Many stools show the branched spike to a marked degree, while in contiguous stools it may be barely noticeable, or quite lacking.

Another spike variation is that where the tip becomes forked. It is not an uncommon form, and appears to be induced by some local factors affecting the spike only. I have never found it multiplied in the stooling process, although a number of times I have found large stools uniformly varying in this way.

The actual yield of hay on a plat of given size is influenced mainly by two factors: (1) The total number of individuals harvested, and (2) the size and leafiness of each individual. With this in mind my own selections included the tallest plants having the greatest amount of leaf surface. The progeny of these was to be tested in order to secure parents of the best transmitting powers.

In this study of leaf characters, a number of points of interest were noted. The quantity of leaf depends upon the number, the length and width of the blade, and upon the length of sheath. The sheath could be either long or short with relation to its internode, and varied greatly in different individuals in its relations to the length of blade. The width of leaf in plants of the same height and side by side, varied from $\frac{1}{4}$ inch to $\frac{3}{4}$ inch. The best plants as a basis for yield improvement were thus judged to be the tallest ones possessing the largest number of leaves having the longest and widest blades and longest sheaths. The next essential step was to determine to what degree desirable characters were inherited by the progeny of each parent. In an attempt at breeding for more useful characters, individuals must be judged by some such method, and progeny records must be begun in the process of securing uniform types adapted to special uses. Another step is to determine what methods of inbreeding, etc., will best preserve these types.

For practical purposes the few notes which I made as a basis for increasing hay production, were rather brief. As an example, a plant was thus described:

Date, July 8. Locality, Granby, Conn.

Head tapering, 6 in. long, and $\frac{3}{4}$ in. wide.

1st internode (from spike) 12 in.; 1st leaf sheath, 9; 1st leaf blade, $6\frac{1}{2}$.

2nd " " 9 in.; 2nd " " 6; 2nd " " $11\frac{1}{2}$.

3rd " " $7\frac{1}{2}$ in.; 3rd " " $4\frac{1}{2}$; 3rd " " $12\frac{1}{2}$.

Very excellent plant, vigorous, leafy. Growing by roadside in very fine sand washed from road, etc. Fibrous roots. Note that these characters are inherited.

Spike characters may not be especially important ones, yet there is a more or less marked relation between their length and the general vigor of the plant. The longest spikes are generally associated with the largest plants. Many spike characters will no doubt be found to indicate useful correlations. For instance, the drooping character of spike seems more or less closely associated with weak-

stemmed types showing a tendency to lodge easily. It is the duty of the breeder to determine as many correlations as he can in the process of simplifying his work.

In many ways timothy improvement appears to be a field of great promise. There are many indications of useful characters among the numerous types that occur. However, it will no doubt be found that many of these persist in response to certain environmental factors. In the breeding of all crops, plant breeders are coming to realize that the greatest gains are made when the forces of heredity that control a useful quality or character are augmented by the most favorable conditions of environment. The more nearly these forces tend in the same direction, the more rapid and direct will be the resultant degree of increase toward greater usefulness. A highly improved strain maintains its excellence best when it is grown in the locality in which it has been selected, for here its environmental adaptation has become more perfect. These fundamental principles must be clearly recognized by the successful timothy breeder.

The remarkable plasticity of timothy in its relationship to factors of environment cannot but have a very important bearing on the breeding methods applied to this crop.

HOW TO MEET THE DIFFICULTIES IN CLOVER BREEDING.

By C. FRUWIRTH,

Professor of Agriculture and Director of Royal Plant Breeding Station, Hohenheim, Germany.

It is safe to say that all the common clovers, as red, white, alsike, alfalfa and sainfoin, have flowers adapted to the visits of insects. This makes the breeding of these plants very difficult.

If individuals are found in the open field showing peculiarities, and if the same are taken to start the breeding of a strain from each individual, success is very uncertain. Each of these individuals has been fertilized from insects and those insects have perhaps in a few cases brought pollen from flowers of the same plant, but surely in the majority of cases from other different and unknown plants not having the characters observed in the individuals under observation. The effect of this mingling of hereditary forces will be apparent in the next generation in a greater or less degree.

Now, by selection all individuals not showing the peculiarities of the chosen plants can be weeded out. In a few cases one can make these selections before flowering, in which case it is comparatively easy to secure results. If it is necessary to the selection that the plants be in flower or ripe, then by each selection one more year is lost. It is necessary to select one year and weed out plants which do not satisfy and let the others bloom and produce seeds the next year. Selection completed, one has now only plants