parents so far as the seasonal and cultural factors are concerned, and there was certainly no falling off in pod-bearing capacity due to untoward conditions.

BEAN BREEDING.

By R. A. EMERSON, *Lincoln, Nebr.*

TYPES AND CONDITIONS INVOLVED.

Beans are grown for so many purposes that the objects sought in breeding them can scarcely be indicated in a general way. It should be pointed out at once that a general-purpose bean is an impossibility. Beans illustrate the value of special types for special purposes as well as any crop known to the writer. In the following account, some idea will be given of the many uses to which beans are put and the particular types which should be kept in mind when breeding beans for these particular purposes.

ADAPTATION TO CLIMATIC CONDITIONS.

Adaptations to local conditions is one of the first things to receive attention. A race of beans may be very good in one locality and worthless in another. The Yosemite Mammoth, for instance, is doubtless an excellent sort in rich soils in mild moist climates, but if we had to depend on this variety in Nebraska, we should go without snap beans. Plant habit is important from the standpoint of locality. Climbing beans are out of the question in a windy country, unless the climate be very dry so that the plants can trail upon the ground. Bush beans, for whatever purpose grown, should be erect and strong enough to hold their pods well above the ground to avoid rust and discoloration if not harvested promptly when mature. This character is not often found in either garden or field beans. It is probably more important in moist than in rather dry climates.

SNAP BEANS.

Several types of garden beans are needed in any locality. The ideal main crop snap bean for home use, in addition to being productive and resistant to disease, must have good quality. The immature pods are the crop. Above all they should be tender; that is, without the development of cross-fibers in the pod walls. Stringlessness, or the non-development of fibers along the sutures, is important, but less so than tenderness, for, in breaking snap beans, the strings can be pulled out, but the cross-fibers cannot be removed and will never cook tender. Fleshiness of pod is a character of prime importance. Most pods are tender and almost stringless when young, and some races are almost perfect in this respect even when their pods are full grown, but without fleshiness they lack substance. An agreeable flavor when cooked is a character not commonly regarded, but there are considerable differences in the flavor of beans. A yellow or

whitish color adds greatly to the attractiveness of green pods, as is evidenced by the popularity of so-called "wax" beans. The seed color is important in wax beans from the standpoint of attractiveness. The ideal is a white seed, though a little color about the eye may not be very objectionable. The value of white seeds in yellow snap beans does not lie, as is often stated, in the possibility of using the dry seed, if the entire crop is not required for snaps. Surely, no one who tried to thresh tender, stringless, fleshy-podded beans will suggest growing them for the dry seed. Colored seeds detract greatly from the attractiveness of yellow snap beans. When cooked they not only show through the pod walls, but they color the liquid in which the pods are cooked, giving it a muddy appearance, especially if milk or cream is added in cooking.

Unfortunately, the ideal snap bean will not answer under all conditions. Green-podded beans are usually stronger and hardier and probably less subject to rust than are yellow-podded ones, and are therefore not to be left out in breeding valuable garden races. Main crop beans, moreover, are not all that are needed. There must be very early races, especially for market gardens. With these, productiveness, and quality, even, may be sacrificed to earliness. A small early crop is often much more valuable than a large late one, and as to quality, early beans are often used or marketed when so small that the strings and cross-fibers have not developed seriously. Moreover, early beans, planted when the ground is cold, must be specially hardy, and all who have attempted to grow beans under unfavorable conditions must have been impressed with the great vigor and hardiness of tough, stringy, green-podded sorts as contrasted with tender, stringless, yellow-podded ones. The seed color of these races is unimportant. In green-podded beans the seed color is masked by the pod color. Moreover, tough-podded beans can be used only when small, before the seeds have colored noticeably.

GREEN SHELL BEANS.

We use garden beans not only for snaps but for the green seeds as well, just as we do with peas. Obviously, green shell beans need not have tender, stringless pods. It is probable, in fact, that the tough, green-podded sorts are better suited to the production of green shell beans, just as in the case of early snap beans. The important things here are large seeds of good quality and large yields. We must have large pods or many of them. Long pods with but one or two seeds each, while not an objection in snap bean races, except from the seedsman's standpoint, are not tolerated in green shell beans. White seeds are important here also, and for the same reason as in the case of yellow-podded snap beans.

DRY BEANS.

With races of beans grown for the dry seeds, just as in the case of most field crops, productiveness is the one great object. The pods must be abundant and well-filled. Certain other characters of seeds

and pods are, however, not to be overlooked. Though other colors are sometimes admissible, white seeds are the rule. No dry bean is ideal that is not white. Small seeds are usually preferred to large ones, and round seeds to long or flat ones, though these things should not be considered of equal merit with productiveness. The chemical composition of the bean seed will doubtless stand improvement. In this connection, the writer need only express his belief that beans, like other crops, should be developed along the special lines in which nature has given them a good start. Beans are naturally nitrogenous. It would seem, therefore, amiss to attempt to increase the starch content at the expense of proteids.

The pod is only indirectly important in the case of dry beans. Nevertheless, pod characters are of great practical importance. The pods should be green, not yellow, and tough and stringy rather than tender and stringless, the former being usually the healthiest, as has been noted above. An added reason for tough pods in field beans is the comparative ease with which they are threshed. The cross-fibers in the pod walls are the special agents for opening the pods and scattering the seeds of wild legumes. They have been bred out of some cultivated beans, for obvious reasons, with the result, however, that these types are very difficult to thresh. A tender pod, particularly if it has been wet often after ripening, breaks into pieces and adheres to the seeds in threshing, while tough pods still retain much of their original tendency to split along the sutures, the halves remaining intact and separating readily from the seeds. This difficulty with some tender-podded races is so pronounced, it is said, that seedsmen find it unprofitable to grow them. Tender pods would therefore be a great disadvantage in field beans.

METHODS OF BEAN BREEDING.

An ideal type of bean for a particular purpose having been conceived, how shall it be produced?

VARIETY TESTS.

The very first thing to do if one would improve any plant is to study the existing forms of that plant. It is still thought in some quarters to be the proper thing to decry variety tests as of no value. Perhaps much of the indiscriminate testing of varieties of all sorts has been overdone. It is, nevertheless, certain that intelligent work in plant breeding must follow a systematic study of the varieties already available. The writer's personal experience may be of value. He began breeding beans before he knew a dozen races even by their names, to say nothing of their racial characters and adaptations to particular climatic conditions. After six years of rambling work in bean breeding and five years of more or less superficial study of some hundreds of races of beans, he is now ready to declare that no one should attempt to breed beans of whom it can be truthfully said, "He does not know beans."

SELECTION FOR RACIAL IMPROVEMENT.

It is not enough to know the general racial characters of beans. Individuals of the same race vary greatly in vigor and productiveness, if not in the more fundamental characters of the race. Undoubtedly, much can be done in the matter of race improvement by selection of productive individual plants; in fact, this is a method in common use. Since the writer's early work was confined wholly to a theoretical study of bean hybrids, he has not given attention to this phase of the subject. I understand from Professor Hays, of Minnesota, that he has succeeded in establishing promising strains from individual mother plants selected on account of their productiveness.

HYBRIDIZATION.

Practically all of the writer's work in bean breeding has been confined to experiments in hybridization. Considerations of an entirely theoretical nature led to his starting the work. In fact, beans, rather than any of the other common vegetables, were chosen, on account of their special fitness for theoretical work. Only recently have the more directly practical problems of bean improvement been taken up. It is therefore too early to have secured practical results in the way of better races of beans. On the theoretical side, however, some interesting results have been secured which are not without their direct practical bearing. No detailed account of these results will be attempted here. The records of this work will appear soon, however.

In the climate of Nebraska it is difficult to cross beans in the field. Unless the conditions are right, beans often fail to set pods satisfactorily, even when the flowers have not been mutilated. In hybridizing beans it is necessary to remove the anthers before the flower buds begin to open, otherwise the seeds will be self-fertilized. Thus mutilated, it is no wonder that poor results have followed work in the dry atmosphere of the field. In a greenhouse, where conditions can be controlled better, little trouble has been experienced in the work. It is probable that this work could be done in the field in a more favorable climate, or even in the climate of Nebraska, if the plants were protected by a good windbreak and, temporarily at least, by a partial shade. When practical results alone are desired, without regard for scientific accuracy, there is little use for a greenhouse or screen, or, indeed, for hand pollination. All that is necessary is to plant close to each other the two races that it is desired to cross, the time of planting being regulated so that the two sorts shall be in blossom together. True, only a small percentage of the seeds thus secured will be hybrids but the total number of hybrids will be large in proportion to the labor involved. The great advantage of doing the work in the field lies in the opportunity for selecting vigorous parent plants from a considerable number of individuals of the races to be crossed.

If accurate scientific results are desired, it will be necessary to keep bees and similar insects away from the hybrids under a frame

entirely enclosed in wire cloth. Of course no such precaution is necessary when practical results alone are aimed at, the probability of crossing being relatively small, especially between groups somewhat isolated.

For practical results, selection may be begun in the second generation, though, unless a considerable number of individuals of this generation are at hand, the desired combination of characters may not appear until the third generation. No general statement can be made at present as to the number of generations of selection necessary in order to fix a new type. Certain types can be selected in the second generation with positive assurance that they will breed true, while other types cannot thus be selected.

As an illustration of how a knowledge of the behavior of bean hybrids may sometimes enable one to breed a particular type with certainty, the following is offered: It is conceived that a white field bean of the bush type would have certain advantages. Such a bean was already in existence in the race known as Vineless Marrow, but unfortunately this race had not proven productive under Nebraska conditions. The common Marrow and Navy races are productive, but "viny" in habit. It would perhaps be possible to select individual plants of these races that show some tendency toward a bushy habit, and, by repeated selection, finally to breed the desired type. Or it might be better to start with the Vineless Marrow and select individual mother plants for greater productiveness. A third possibility would be to cross Vineless Marrow with Navy or common Marrow. Past experience has shown, however, that few very productive bean hybrids are to be expected where either parent is decidedly unproductive. What was actually done was to select, without reference to seed color, two races of bush beans which had proven exceedingly productive and which at the same time were very stout and erect in habit, holding their pods well up from the ground. They were "Ne Plus Ultra" and "Marvel of Paris." Both races have tough stringy green pods—very desirable characters in field beans. Ultra has yellowish brown seeds, and Marvel of Paris mottled seeds of a dark bluish drab in general appearance—peculiar colors, it will be admitted, from which to breed white beans. These races were crossed with Marrow and Navy. All the individuals of the first generation were viny in habit and had mottled, mostly dark-colored seeds—not a very promising start toward a bushy, white-seeded race. The second generation, however, afforded both viny and bushy types, and both colored and white-seeded forms. All the plants, of course, have tough, stringy, green pods. A number of productive, erect, bushy plants, with white seeds, have been selected for propagation next year (1904). From results secured with other similar hybrids, there is scarcely a doubt that these selected forms will breed true as regards the important characters, a bushy habit, and white seeds. Had it been desired to produce a viny race from the cross, individuals that would breed true could not be selected with certainty until the third generation, and from the records at present available, it cannot be told whether seed colors other than

white can be fixed except by long-continued selection. When complete results are secured with other characters, such as stringiness, toughness, fleshiness, shape and color of pods, it may be possible to bring about many other desirable combinations of characters in this summary manner. If this prove true, it will illustrate well the fact that results of a theoretical nature may in the end prove of the utmost practical value.

TEACHING THREMMATOLOGY.

By DEAN EUGENE DAVENPORT, *Urbana, Ill.*

I have been asked to contribute a short paper upon the teaching of thremmatology, as we are beginning to term that phase of evolution which deals with the improvement of domesticated animals and plants.

For a variety of reasons I find the subject a most difficult one to reduce to pedagogic form. Some of these reasons are worth mentioning here.

1. The theories of evolution are not only many but in vital respects diametrically opposite. For example, what could be at greater variance than Weisman's theory of determinants, and Romane's easy inheritance of acquired characters? Moreover, the point at issue is second in importance to none in thremmatology.

2. These opposite and even antagonistic theories are announced in sweeping terms and supported by a curiously selected mass of facts that serve their purpose well—an admirable example of natural selection or of adaptation, to say the least; for in many cases facts enough are left out of consideration to support an exactly opposite contention. A good example of this is the theory of the absolute distinction between germ plasm and somato plasm, in face of the well known facts of complete regeneration, even, as in a begonia, from so small a part as a leaf. Another is the assumption that all characters are or have been adaptive and formed by natural selection, when even a casual review of the situation would reveal the fact that almost any species is struggling along under disadvantages to which natural selection is oblivious.

3. The largest masses of facts available have been collected in support of peculiar theories and a cloud of doubt is thus often thrown around what ought to be the most valuable evidence. Even some of the best writers permit themselves to become hopelessly befogged; for example, few authors in discussing variations make it clear to the reader whether they mean deviation in the character of the individual or the type of the race, or even perhaps only differences between contemporaneous individuals. Stranded in these shoals, more than one author, becoming impressed with the power of selection in altering the type, has gravely announced selection to be the fundamental cause of variation.