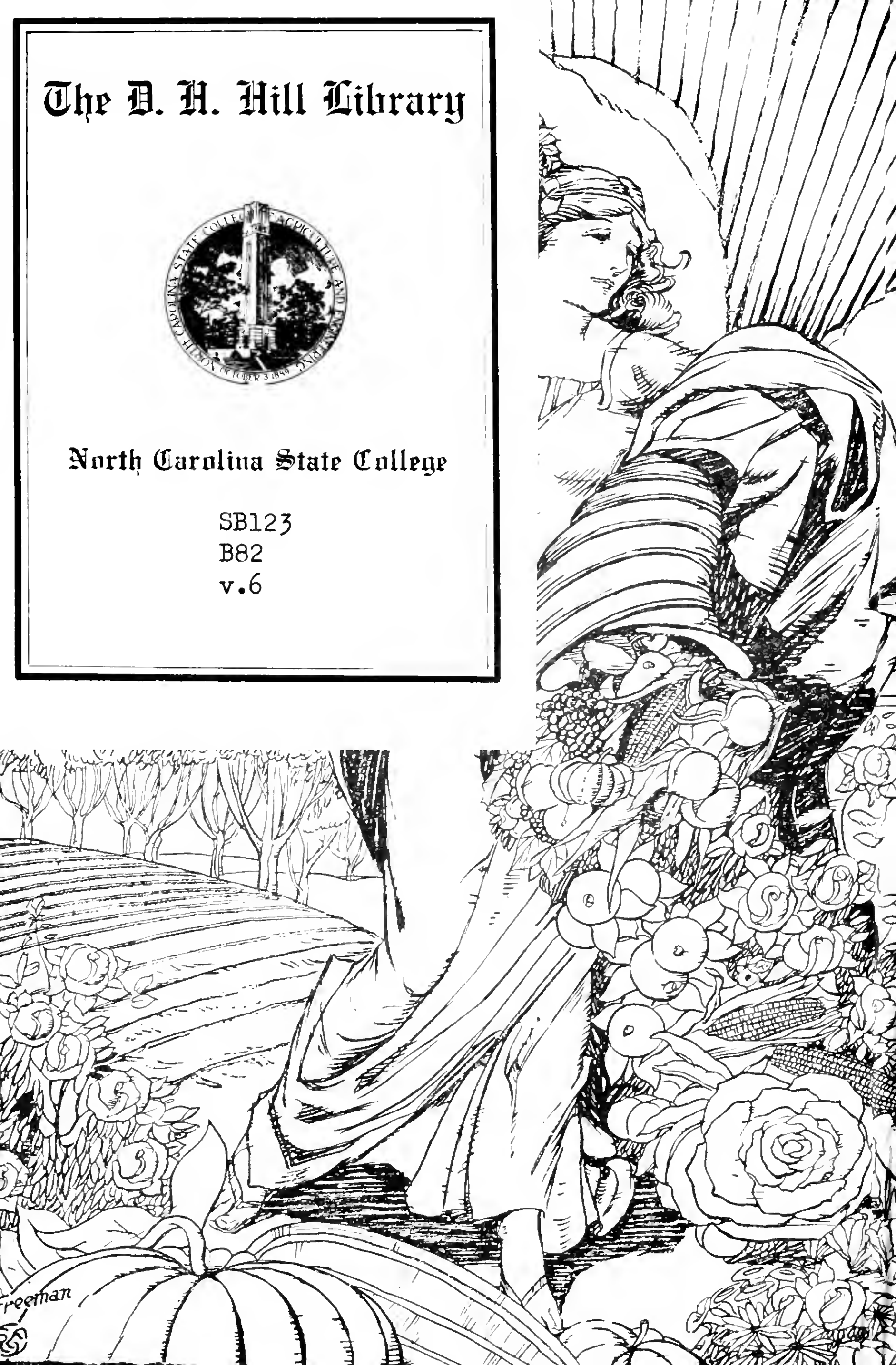
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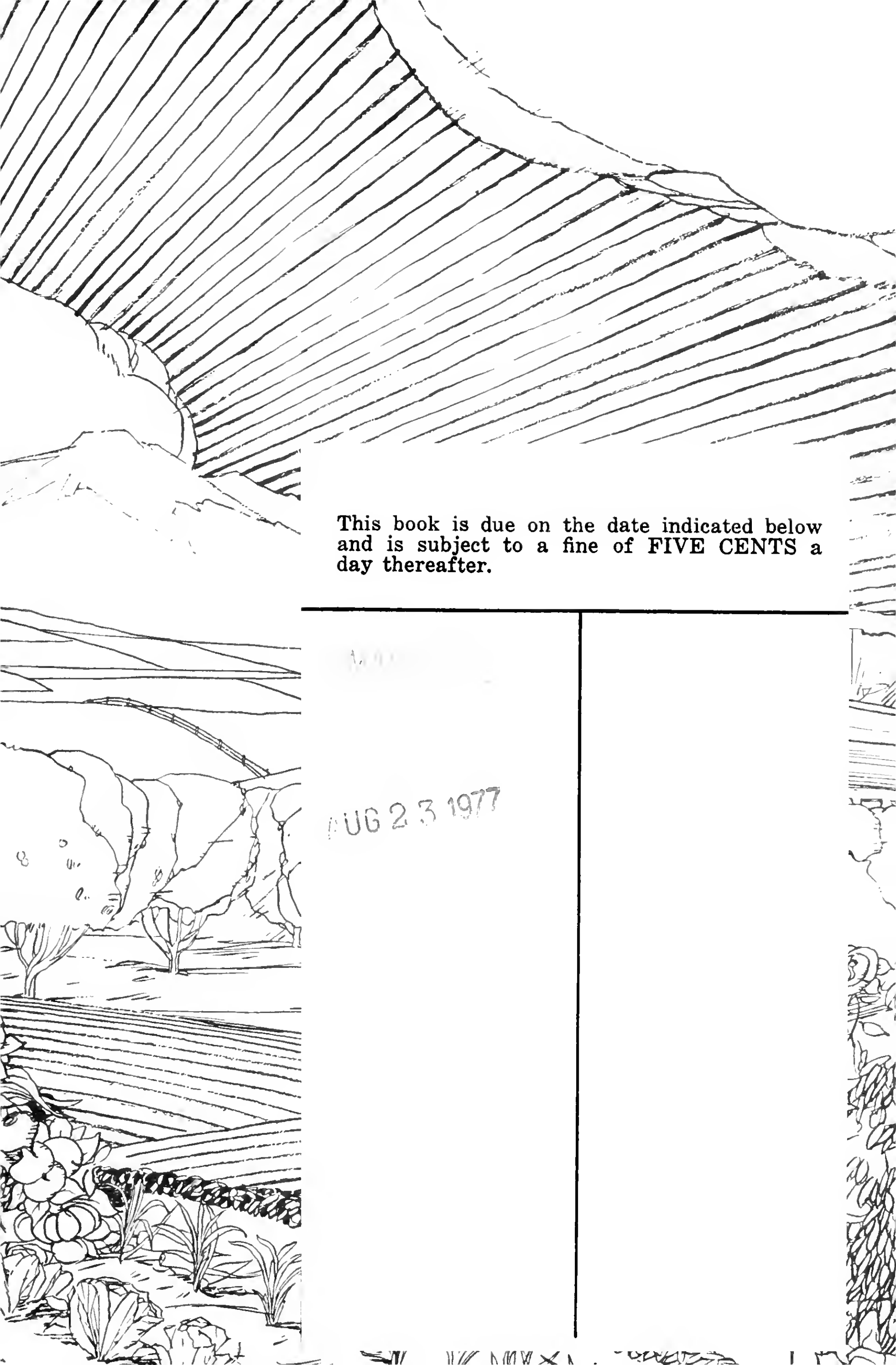

ARTIFICIAL RAIN IN MR. BURBANK'S GARDEN

Mr. Burbank uses and recommends a sprinkling apparatus like that shown here. It consists of long pipes attached to a hose, each pipe having little nozzles at intervals of a few inches, thus sending forth a series of tiny streams which, rising high in the air, descend on the plants in a shower that closely simulates rain from the clouds. The pipes can be turned to throw the spray in either direction, and to regulate the distance at which the shower descends. Remember always that water is food for the plants—absolutely indispensable food.

HOW PLANTS ARE TRAINED
TO WORK FOR MAN

BY LUTHER BURBANK Sc. D

USEFUL PLANTS

VOLUME VI

EIGHT VOLUMES · ILLUSTRATED
PREFATORY NOTE BY DAVID STARR JORDAN

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IMPROVEMENTS IN WHEAT, OATS, BARLEY

Mendelian Clues

THE essential facts of Mendelian discovery with regard to "unit" characters and their grouping into pairs, in which one character is dominant and one recessive, have been more than once called to our attention and have been illustrated again and again with instances drawn from my own plant experiments.

The cases of the black and white blackberries, the thorny and thornless blackberry, and of stone-bearing and stoneless plums, among others, will be recalled.

But we have also observed cases in which the characters of two parents seemed to be blended in the offspring, there being no clear dominance of one character over another. Such was the case, for example, with the sunberry, the primus berry, the plumcot, and many others.

Now it is peculiarly interesting to note, in the light of our experiments with various fruits and flowers of widely different orders, that Professor Biffen was able to analyze the diverse qualities of the various wheats with which he experimented and to discover that different groups of unit characters operated differently in heredity. Some of the pairs showed dominance and recessiveness; others showed an irregular or partial dominance; while other pairs showed the blending of characters, so that the offspring was intermediate between the parents, there being no apparent tendency to dominance or recessiveness.

Yet all of these characters, whether manifesting the phenomena of dominance in the hybrid of the first generation or not, showed the same tendency to segregation in the succeeding generation, and to segregation along the familiar Mendelian lines; that is to say, one offspring in four would reveal the first character only, the second and third offspring were mixed as to the pair of characters, and the fourth would show only the second character.

It was necessary only to plant the individual grains of wheat in plots by themselves, and to note the qualities of the grains of each (that is to say, the qualities of the offspring of the first filial generation) to make sure as to the position of each individual in the Mendelian scale (whether pure or mixed in its heredity as to its given factor), and thus to be able to select pure types that would breed true; and, what is perhaps equally important, to eliminate the impure types that would not breed true.

Dominant and Recessive Characters

It will be of interest to note a few characters that Professor Biffen particularly studied and the groups into which they fall.

As to characters that show the phenomena of pure dominance and recessiveness, the following among others were clearly revealed: Beardless ears of grain are dominant to the bearded ears; keeled glumes to round glumes; lax ears to compact ears; red chaff to white chaff; red grain to white grain; thick and hollow stem to thin and solid stem; rough leaf surface to smooth leaf surface; bristles on the stem to a smooth stem; hard translucent endosperm (central grain substance) to soft opaque endosperm; and, finally, susceptibility to the attacks of yellow rust was dominant to immunity to yellow rust.

This implies, as the reader is aware, that in each case of those just listed, when two plants represented by the opposite characters are crossed, the offspring will show the first-named character to the exclusion of the other in the first generation, but the excluded character will reappear in one-fourth of the offspring of the second generation.

Breeding a wheat with beardless ears and white grain, for example, with a wheat having bearded ears and red grain, all the progeny will be beardless and red-grained; but bearded ears and white grain will reappear, in various combinations, in one-fourth of the progeny of the second generation.

It is never safe for the plant developer to draw exact inferences as to the hereditary tendencies of one plant from observation of a quite different plant. Nevertheless, it is of interest to observe certain analogies between the wheat grains as studied by Professor Biffen and certain of our plant development already cited.

In particular we may note that red grain is dominant to white grain, suggesting what we have said as to the dominance of black blackberries over white blackberries.

Again, the rough leaf surface and bristly stem of the wheat proved dominant to the smooth leaf and smooth stem, suggesting the case of our thorny-stemmed briers in which the thorns proved dominant to smoothness of stem.

But doubtless the most important revelation made by Professor Biffen's investigation was the fact that susceptibility to rust was dominant to immunity to rust.

This means that when a susceptible type of wheat is crossed with an immune one, all the offspring will be susceptible. But it means also that the recessive quality of immunity will reappear in one-fourth of the offspring of the second generation.

And thereby hangs the tale of Professor Biffen's achievement, as will appear in a moment.

Characters That Do Not "Mendelize"

Before following this let us glance at the other groups of unit characters which Professor Biffen found not subject clearly to the rules of dominance and recessiveness.

These groups include fewer characters than those in the dominant list, partly perhaps because it is obviously more difficult to study characters that do not show the clear phenomena of dominance and recessiveness. But these groups are highly interesting none the less. The unit characters that showed what Professor Biffen speaks of as irregular dominance as studied in this investigation, were only two, namely: (1) felted glumes versus glabrous glumes; and (2) gray-colored glumes versus red or white glumes.

The glume, perhaps it should be explained, is a bract that has no particular interest for anyone except the botanist, but which may serve admirably in checking the results of experimental breeding. The glumes have practical significance for the agriculturist, because their character determines to some extent the readiness with which the grain is shelled out in the thresher.

The interest in the different types of glumes as to smoothness and of color, in the present connection, centers about the fact that neither parent showed dominance in the first generation of the hybrid, the individual hybrids differing indefinitely.

In some cases there would be almost pure dominance; in others a blend of the characters. But in the second generation the characters were segregated just as if they had shown the typical phenomena of dominance and recessiveness in the first generation.

The third group of characters, in which there was uniform blending in the first generation of hybrids, with no tendency whatever to manifestation of dominance of one character over the other, found representation in the following pairs of unit characters: (1) lax ears versus tense ears; (2) large glumes versus small glumes; (3) long grains versus short grains; (4) early habit of ripening versus late habit of ripening.

As to each of these pairs of characters, the hybrids of the first generation were intermediate between the parents. For example, if a wheat having long grains was crossed with one having short grains, the hybrid bore wheat neither long nor short but intermediate; and if a wheat that ripened early was crossed with one that ripened late, the hybrid offspring ripened their grain at an intermediate season, later than their early parent but earlier than their late one.

Yet here again—and this perhaps is most significant of all—there was segregation of characters in the second generation along the usual Mendelian lines. That is to say, the first generation hybrids that bore grain of medium length will produce offspring one-fourth of which bear long grain and one-fourth short grain, the other half bearing intermediate grain; and similarly the first generation hybrids that ripened their grain at an intermediate season, produce progeny one-fourth of which ripened their grain early and one-fourth late, the other half ripening their grain at the intermediate season.

The importance of this observation is that it shows that the Mendelian principle of the segre-

RESULTS OF WHEAT EXPERIMENTS

A sample cluster of varying wheat heads from the garden in wheat experiments were made one summer. A glance shows the extraordinary range of variation among these crossbred wheats. Here are differences that suggest the possibility of developing any number of new varieties.

gation and recombination of unit characters in second generation hybrids follows the same rule whether or not the characters show clear dominance in the first generation.

And if we look a little beneath the surface it will appear that there are hundreds or perhaps thousands of unit characters that for one reason or another do not show the phenomena of dominance in the first generation and hence are exceedingly difficult to trace, and yet which reappear segregated in new and varied combinations in the second generation, thus accounting for the extraordinary diversity of second generation hybrids to which our attention has been called again and again.

It is interesting to note that Professor Biffen found such conspicuous conditions as long grain and short grain to fail to manifest the phenomena of dominance and recessiveness.

Considering that tallness of vine had shown itself to be dominant over shortness of vine in Mendelian peas, it might perhaps have been expected, reasoning from analogy, that long grains of wheat would be dominant to short grains.

But I have already suggested that *it is unwise to attempt to predict the hereditary tendencies of one plant from observation of another;* and in particular it should be said that the stems of plants, as regards their fixity of hereditary tendency, are likely to be on a different plane from the flowers or fruit, or any other new characters.

The particular arrangement of floral envelope that characterizes the plant of to-day is of relatively recent development, and may be expected to be subject to greater fluctuations, or, in other words, to show greater plasticity under the disturbing influences of hybridization. Professor Biffen even found that there was a difference in the manifestation of dominance and recessiveness with regard to certain characteristics between different varieties of wheat.

Thus, in the matter of the glumes, where the parent that bore a felted glume was the variety known as "rough chaff," the felted glume proved dominant over the smooth glume. But where the felted parent was the variety known as rivet wheat, the phenomena of dominance was irregularly manifested, or manifested not at all. So hybrids of the rivet wheat were listed in the class of irregular dominants, as above outlined.

Practical Application of the New Knowledge

Having thus analyzed his wheat plants and made himself familiar with their hereditary possibilities, Professor Biffen was ready to make application of his knowledge to the improvement of existing varieties of wheat.

In particular he desired to produce a variety of wheat that would be immune to rust, yet would at the same time produce a good head of wheat having the quality described by the miller as "hardness"—a quality that is essential to the making of high-grade flour, yet which some otherwise excellent wheats altogether lack.

Material was at hand for crossing experiments in that there was a race of wheat known to be immune to the yellow rust which had not hitherto been thought of as solving the rust problem because it bore grain of very poor quality.

To Professor Biffen, armed with his new knowledge, it appeared that it should be possible to combine this immune wheat of poor quality with susceptible races of wheat bearing a good grain in such a way as to secure a new race that would present the good qualities of each parent and eliminate the bad qualities.

So he crossed a race of wheat that bore a grain susceptible to rust with the immune variety that bore the grain of poor quality, and developed a generation of crossbreds all of which were—quite as he had expected—susceptible to the attacks of the rust.

A SHEAF OF OATS

Two of my new oats, also, are taking their place as best. One of these is a giant-growing kind, the other a new, fat, productive, hull-less oat.

To the untrained plant experimenter it would have appeared that this experiment should be carried no further. Progress was apparently being made in the wrong direction; for whereas half the parents were immune to rust, all of the children were susceptible.

But Professor Biffen knew, as we have already seen, that susceptibility and immunity constituted a Mendelian pair of hereditary factors. So he knew that in the next generation one-fourth of the hybrid plants would be immune to rust. And this expectation was justified by results. The second generation hybrids showed diverse combinations of various other qualities that were under consideration, and a certain proportion of them revealed the combination of the desired quality of grain with the stems immune to the attacks of the rust fungus.

As immunity to rust is a recessive factor, it follows that the second generation hybrids that show such immunity will breed true to that character. Their offspring will be immune. But as regards certain other qualities, notably hardness, it was necessary to continue the experiment through a third generation, in order to discover which of the plants that were individually hard were pure dominants as regards the quality of hardness.

To ascertain this it was necessary only to plant the grains showing the desired quality in plots by themselves.

The individuals that produced only hard-grained offspring in the next generation were thus shown to be pure dominants for that quality. They constituted a fixed race and could be depended upon to breed absolutely true.

Thus the clear recognition of the qualities of Mendelian segregation, as applied to the different pairs of unit characters representing respectively desirable and undesirable qualities of the wheat, enabled Professor Biffen to produce in the third generation a fixed race of wheat having the desired qualities of grain and a plant stem that is immune to the yellow rust.

The seeds of this new variety being multiplied as rapidly as possible, a wheat was produced that promises to be of enormous importance to the grain growers of England.

It is obvious that a similar line of experiment should enable the plant developers of other countries to produce new varieties of wheat that will be immune to the various rusts, and thus to rid the agriculturist of one of the pests that of all others has hitherto rendered his calling precarious.

Possible Aid from the Wild Wheat

My own extensive and very expensive experiments with wheat and other grains have been carried on for many years and the results, though not very profitable to myself financially, have proved, even at this early date, that they will add many millions of bushels of far better grains not only to the American farmer, but also to the growers of other countries where they are now rapidly supplanting other grains for resistance to rust and in larger, whiter, and harder kernels and ability to stand up where other grains fall during storms. And better yet, by analysis, as well as by baking test my "Quality" wheat stands at the apex, and the improvement in other grains is now being fully appreciated by growers in both hemispheres. All my experiments, of every nature, have been carried on for fifty years without any outside aid from any source, except the welcome given them by growers and the sums received from them as they have been from time to time introduced.

Much further investigation will be needed before we can make sure as to the material that is available. But peculiar interest attaches to the investigations recently made by Mr. O. F. Cook, the biometrist in charge of crop acclima-

SAMPLE HYBRID SUNFLOWER

Interesting and beautiful hybrids are quite readily produced, and these variations are fixed so that they may be depended upon to come true from seed with attention to keeping the new varieties from crossing with others, and a careful weeding out of those not coming strictly up to the new standard.

tization and adaptation of the U. S. Department of Agriculture, with reference to the wild wheats of Palestine, which were discovered by Mr. Arronson, a native of Palestine.

Mr. Cook's reseaches have shown that there are races of wheat growing wild in southwestern Asia that are prototypes of the cultivated wheat. The resemblance of these wild forms to the cultivated varieties is striking. Yet the differences are also very conspicuous. The wild wheat has a looser, less compact head, and some varieties have the peculiarity of shedding the spikelets that hold the grain individually, each spikelet being provided with a barbed shaft which serves the purpose of helping the grain to attach itself or even to bury itself in the soil. All of which would be expected in a wild wheat, which is found also in the wild oats and rye as well as in rice.

The kernels of these wild wheats are not large, but some of them are of more or less edible quality.

A chief interest in the plant centers about its seeming immunity to rust. And the question at once arises as to whether it may not be possible to hybridize these wild wheats with the cultivated ones to secure resistance to disease as well as unusual variation, vigor, and hardiness.

Tests calculated to discover possibilities in this direction are now being made, and there is some reason to hope that they will have valuable results.

It may be added that the wild wheat is not universally self-fertilized. The stamens and pistils of its flowers sometimes protrude and permit cross-fertilization by the aid of the wind or insects. This may to some extent facilitate the hybridizing of the wild wheat with cultivated wheats.

But, on the other hand, it will probably be desirable to eliminate this propensity from the new varieties after they are fixed for commercial use. For, as already pointed out, there are great advantages in the self-fertilization of a grain like wheat, to prevent deterioration of the type by undesired crossing.

But the question of the hybridizing of the domesticated wheat with the wild type remains for future investigation.

As I have already pointed out, this work is preeminently one that should go forward under Government auspices. My own experiments in this line with the wild wheats are necessarily limited.

A work that involves matters of such vast economic significance, having direct connection with the cost of living as applied to every member of the community, should not be hampered by any financial restrictions, and should have the cooperation of investigators in many parts of the world; such cooperation as a government bureau alone can command.

The little company of grasses, represented by wheat, rice, barley, rye, and oats, have since prehistoric times occupied a preeminent position in supplying man and his domesticated animals with suitable foods.

FOOD FOR LIVE STOCK

Some Suggestions on Clover, Timothy, and Alfalfa

FORTY million acres devoted to it; an annual crop of seventy million tons, valued at something like three-quarters of a billion dollars.

Such is the record of hay in the United States.

And of course this takes no account of the other millions of acres that are devoted to pasturage, much of which would be hay if it were not harvested directly by browsing live stock. Just how much this would add to the value of the crop it is difficult to say. But without attempting an exact computation, it will be clear that the value of the forage crops in America reaches a colossal figure.

There are many kinds of grass that may be found first and last in pasture and hayfield, but the one grass that overshadows most others, especially in the Eastern States, because of its universal popularity is that known as timothy in most regions, and in some regions as herd's grass (*Phleum pratense*).

It may be of interest to recall that each name is merely borrowed from the name of the man who was instrumental in introducing this particular grass; one man being Timothy Hanson or Hanse, of Maryland, who is said to have brought the seed from England in 1720; the other being John Herd, who is alleged to have found the grass growing wild in a swamp in New Hampshire as early as 1700.

One of these men distributed the grass through Virginia and Carolina, the other through New England and New York.

From these regions it has spread in every direction, proving adaptable to all climates and soils, until it assumes preeminence in the pasture and hayfield quite unchallenged except by members of the clover family, with which it is often associated.

The clovers, to be sure, are not grasses in the technical sense of the word. Nor, indeed, have they the appearance of grasses even to the eye of the most casual observer. But they rival the grasses in their importance as fodder plants. In certain regards, as for instance in the amount of protein they bear, they outrival the grasses. Also in their capacity to produce successive crops in the same season, some of the clovers, notably the more recently introduced alfalfa, are superior to the grasses proper.

But in general clover and timothy are mixed to form the hay crop, the clover growing densely near the ground, and the timothy rising above it, and the two making a blend that is found exceedingly palatable by all herbivorous animals.

The fragrance of new-mown hay suggests palatability to the human senses as well, and even though the hay crop furnishes food for man only at second hand, no one would be likely to question its wholesomeness.

Improving the Clovers

There are certain of the clovers, nevertheless, that have a poisonous principle. Notable among these is a form of sweet clover not distantly related to the alfalfa, which grows in some of the States of the Middle West and produces an enormous crop which would have great value were it not that unfortunately the tissues of the plant contain a considerable percentage of a bitter alkaloid called brucine, which is highly poisonous, being closely related to the well-known drug strychnine.

A few years ago I received from Kansas seeds of this plant, with the request that I develop from it a variety in which the brucine is reduced to a minimum, or, if possible, wholly removed.

The seeds received were of various colors. My first move was to have the seeds sorted, placing white ones, black ones, and green and brown by themselves. They were then planted in separate lots; a fifth lot being reserved for a mixture of the seeds of uncertian shades.

Thus it was possible at the outset to determine whether the production of plants having a large brucine content was associated with any particular color of seeds. Should such be found to be the case, the experiment would obviously be shortened, as only the plant bearing the minimum amount of brucine would be used for further testing. Experiments showed that the plants from the white seed apparently contained an appreciably less quantity of brucine than the black ones.

As an additional element in the selection, I chose, as is my custom, the seed plants that started very early in the spring. From among these the next selection was made of the plants that had broad foliage and continued to make a very strong growth. Thus several objects were attained almost from the outset. A second selection along the same lines showed that some plants have a much smaller brucine content than others, and that it will be quite possible to separate these and thus produce a variety relatively free from poison.

Some similar experiments in improving peas, beans, and other plants related to the clovers, gave full assurance that I should be successful in the present instance, merely by selective breeding, in producing a plant with relatively low brucine content, and the experiments even in their initial stages justify this belief.

Whether it may be necessary to resort to hybridizing experiments in order to eliminate the brucine altogether or to reduce it to a negligible minimum, remains to be seen.

These experiments were begun only in 1910.

It should be explained that the hybridizing of the plants of this group is relatively difficult, because the flowers are incased in a closed receptacle, as with peas and beans, which belong to the same family with the clovers.

All of these so-called leguminous plants—and they are outnumbered only by the composite flowers—bear the stamens and pistils thus guarded, and are normally self-fertilized.

As already pointed out, this makes the experiment of hand-pollenizing these plants a rather tedious one. In the case of the clovers, the flowers being very small, it becomes a somewhat delicate operation as well. But the later stages of the experiment are greatly facilitated by the fact that the flowers are self-fertilized. With these plants, as well as with small grains, this becomes an important aid in fixing a type, and in maintaining a pure race once it has been developed.

For the most part my experiments with the clovers have been made through selection and without resort to hybridization. But in exceptional cases I have cross-pollinated these plants, to test the possibilities of work in this line. I found that the process involves no great difficulties notwithstanding the small size of the flowers.

In practice I found it better to remove all but two or three flowers in a clover head.

The remaining ones have the petals and the stamens removed with a small pair of forceps, after which the application of pollen from another clover head presents no special difficulties; care being taken, of course, to see that the pistil is at the right stage of development.

Developing New Characteristics of Stem and Leaf

In the course of these experiments I have grown in the neighborhood of two hundred species of clover. Many of these are native species, some of which invaded my grounds unasked. Others have been received from far-away regions, in particular from Peru, Bolivia, and Chile.

Whereas the white clover in its common native forms is a relatively small plant, dwarfed besides the red crimson clovers, there are South American species or subspecies that are of relatively gigantic growth. One of these that I received from South America was a seeming "sport"—possibly due to an accidental hybridizing with some other species—that grew several times as fast as any of the others in a lot of seedlings.

A single plant of this giant variety would spread from four to six feet, the foliage being proportionately enlarged, while a neighboring plant would perhaps grow ten to fifteen inches.

Selection among these rapid growers enabled me to develop several varieties that had the characteristic of growing to quite uncloverlike size. But there is no sale for new clovers unless the seed can be furnished by the ton, and as I had no opportunity to produce seed on a large scale, the giant races were ignored, when they had ceased to interest me from an experimental standpoint.

For a number of years I worked also upon a clover that, without having exceptional qualities of stem, produced a very large foliage. In this case also the development was made solely by selection, the largest leafed individuals of a fraternity being selected for preservation generation after generation.

In the same way I produced a five-leafed strain of clover from a sport that appeared among plants of the usual three-leafed type of white Dutch clover (*Trifolium repens*).

The four-leafed clover is of course well-known as an occasional sport. A five-leafed clover will appear in a lot of seedlings now and again, and there will be found a few five-leafed individuals among the plants grown from seed of this sport. It would, however, require many repetitions seemingly to fix a five-leafed race, the tendency to reversion to the familiar three-leafed type being of course very pronounced.

Another anomaly consisted of a clover with leaves beautifully colored—variegated in black, brown, crimson, scarlet, yellow, white, and green, in different forms and figures, no two plants being closely similar in the coloring of the leaves. This plant was introduced as a new ornamental variety, but as the original plant came from a warmer climate it did not thrive in the Eastern States and has probably been allowed to die out altogether. I have another stock of this which came from chance seedlings, but in no respect equal to the well-bred type formerly possessed.

One of the clovers found on my Sebastopol farm has the color intensified to a bright, rich crimson, which has been reproduced exactly from seed. This is probably a species introduced from South America. A very marked tendency to variation is shown by a large number of clovers when brought to California from distant regions.

The Coming of Alfalfa

Doubtless the most important of the clover importations is the plant that has become familiar as alfalfa (*Medicago sativa*).

This is a form of clover, of which there are several species and almost innumerable varieties, that is adaptable to relatively arid regions, inasmuch as it sends its roots to a depth of sometimes ten or even fifteen feet in search of moisture and nutriment. Such a plant, once it has attained a fair growth, is almost independent of the rainfall for months together. Moreover, the vigor of root of the alfalfa is duplicated by the complementary growth of its foliage, which develops so rapidly and so persistently that it may be cut three, four, and even five times in the season, depending upon climate.

The enormous productivity of alfalfa, together with its adaptability to arid regions, led to glowing predictions as to the importance of this new forage crop, when it was first introduced years ago. In the southwestern part of the country the predictions have been more than justified, but alfalfa for a time failed to make its way in the Eastern and Northern States as rapidly as had been expected.

The principal reason for this is that our most common alfalfa was brought from Peru or Bolivia. Had the plant come from Patagonia or southern Chile instead, or from Russia, its original home, being therefore represented by hardier varieties, it would probably have spread all over the Eastern States and have added vastly to the value of the forage crop everywhere.

But now hardier types of alfalfa are making their way to the North, and even into Canada, and possibly selective breeding will develop races more resistant to frost than any that have hitherto been imported.

A form known as Turkestan alfalfa has lately been introduced that is recommended for its hardiness. When grown side by side with the ordinary alfalfa on my place, it is difficult to distinguish the two plants. But the Turkestan variety may of course have qualities of hardiness that are not revealed in its appearance. There are other strains being grown that are said to be even more hardy.

The alfalfa has so recently been introduced that it has not been very extensively experimented upon. There is no plant, however, which can be taken up for development to better advantage by the Government than this thrifty and drought-resisting clover. With this plant, as with the cereals, work should be carried out on an extensive scale by some one who has opportunity to test the plants in a comprehensive way.

As already noted, it is useless to develop a small quantity of seed of a new variety, as the practical stock raiser will not be interested in the seed until it can be offered by the ton.

Some Other Clovers

I have received a large number of alfalfas and clovers from the mountains and plains of Chile, and have been struck with the close similarity between some of these and the clovers that have invaded my gardens. Others, however, are individual in appearance and differ markedly from any that I have seen elsewhere.

Among the Chilean clovers that I am now testing is one that is a giant in its proportions as to leaves, foliage, growth, and blossoms.

Another of the Chilean clovers has a heart-shaped brown spot on the leaf. The bloom and seed of this variety closely resemble the common bur clover, but the leaves are several times as large as those of that plant.

The bur clover (*Medicago denticulata*) is of peculiar interest because it produces enormous quantities of seed that fall from the stalks when ripe, and in our dry climate may remain edible for some months.

The plant was at first thought to be a nuisance, but its value in a region where there is no rain for months together soon came to be recognized. To anyone who is not acquainted with the bur clover it is matter for astonishment to see a herd of sheep, cattle, or horses, or a drove of hogs pastured in a field where there is not a vestige of green herbage; and yet to note that these animals are well-conditioned and even fat. They feed on the bur clover seed, the pods of which sometimes cover the ground half an inch or more in depth.

The plant itself has withered and disappeared, but the seed-bearing pods furnish a forage crop that has no substitute in this region, although it would probably be unsuited to the East.

The bur clover has a small leaf and small blossoms. It runs and spreads by long, wiry, slender stalks, and does not stand upright, so that it could never be profitably cut for hay, making only a tangle of tough threadlike stalks. Yet its peculiar property of producing an abundant crop of pods makes it in some localities quite as valuable a pasture plant as the common red clover is in the East.

Neither the crimson clover (*Trifolium incarnatum*) nor the common red clover is extensively grown on the Pacific Coast. White clover is cultivated for lawns, mostly in combination with blue grass. It will often cover a bare spot under a tree where the blue grass does not thrive.

Alsike clover (*T. hybridum*) is another form that is seldom seen in California, partly perhaps because it does not tend to send its roots deeply into the soil, and hence is not as well adapted to a dry climate as are the alfalfas. On the other hand, it thrives on a clay soil, and in regions to which it is adapted it is a valuable product.

There are numerous other species of clover that have as yet been almost neglected by the plant developer, which offer inviting opportunities.

Even without hybridization, plants grown from a given lot of seed will vary greatly. Selection among the most familiar races of clovers would readily result in the development of new varieties that might be of enormous value. The fact that the plant thrives more or less under disadvantageous surroundings has partly accounted, no doubt, for its neglect by the plant developer. But now that year by year there is a growing recognition of the need of intensive cultivation of farm crops, the clovers are sure to come in for a larger share of attention.

Other leguminous plants, including the peas and beans as well as the clovers, have long been known to be characterized by the unusual amount of their protein or nitrogenous content.

The Food Value of Clover

This has led the plant physiologist to regard the clovers as having an exceptionally high food value. As compared with timothy grass, for example, clover contains, pound for pound, a very much larger amount of nitrogen. As nitrogenous foods are the muscle builders, the value of this is obvious.

There has been a tendency in recent years, to be sure, to question whether the nitrogen content has quite the significance that was formerly ascribed to it. It has been pointed out that horses do not need a very large amount of protein foods unless they are exercising actively, and that in this event they usually secure an adequate amount of protein in the grains, chiefly oats, that are fed them.

Cattle that are being fattened may thrive as well on foods that are less rich in protein.

Milch cattle, and growing cattle, on the other hand, need a nitrogenous diet. And, indeed, all along the line, it is not to be denied that a protein food has exceptional nutritive value. It is partly at least with this in mind that the intelligent agriculturist mixes clover with the timothy in his pastures and in his hayfield.

At least a partial explanation of the high nitrogen content of the leguminous plants has been furnished by the discovery that these plants have the very unusual capacity to extract nitrogen from the air. Most plants, as we have seen, are quite powerless to take even the most infinitesimal quantity of nitrogen from the air, and would starve to death for lack of nitrogen even while their tissues are perpetually bathed in it—as the tissues of all aerial plants necessarily are—inasmuch as the atmosphere contains nitrogen as its most abundant element.

But the leguminous plants are able to extract nitrogen from the air directly; not, however, with the aid of their leaves or stems, but only by way of the roots, and there only with the aid of the little tubercles that develop under the influence of microorganisms. It is, indeed, the micro-organism that extracts and fixes nitrogen and makes it assimilable for the plant.

The tissues of the plant itself have no direct share in the work, beyond giving hospitable refuge to the microorganisms themselves.

The little tubercles that form on the clovers and the allied plants vary in size and shape with the species of plant, although the microorganisms that produce the tubercles and that assist the plant in securing a supply of nitrogen are closely related. There are, however, different groups of microorganisms that are able to produce the tubercles and help in nitrogen fixation.

As microorganisms are not always present in any given soil, it has been found sometimes desirable to inoculate the soil in which various clovers are to be grown.

This may be done by scattering over the field soil from a field in which tubercle-bearing plants of the same species have been grown the previous year.

It has been clearly demonstrated that such inoculation of the soil may lead to much freer growth of tubercles than would otherwise take place, and to the increased vigor and growth of the clover crop. The use of artificial cultures of nitrifying bacilli has also been recommended. It is necessary, however, to treat the solution in a particular way in order to insure that the micro-organisms may maintain vitality. If they are dried slowly under the usual atmospheric conditions, the microbes die.

It has been found possible to preserve them by rapid drying of pieces of cotton dipped in a solution containing the microbes.

The Department of Agriculture at Washington has experimented with a method of distributing liquid cultures in glass tubes. Special packages of minerals, including phosphate of potassium, sulphate of magnesium, and ammonium phosphate, are sent with the culture tube to make a nutrient medium in which the culture may be developed.

The clover seeds are moistened with this liquid culture, dried rapidly, and sown as quickly as practicable.

Another method is to sprinkle the liquid on a portion of soil and scatter this over the land.

This inoculation of the soil with the nitrogen-fixing microbes constitutes a new departure in agriculture that would have been quite incomprehensible to anyone before the day of the modern bacteriologist. But so much has been learned in recent years about the bacteria and their almost universal prevalence and share in the vital activities of animals and plants that the sprinkling of the soil with bacteria seems almost as commonplace a deed as the sowing of seed.

This method, however, is obviously only an accessory to the methods of the plant developer. It has exceptional interest as illustrating the application of science to the art of agriculture, but it has no direct association with the work of the experimenter who develops plants by hybridizing and selection.

Just how the leguminous plants came to develop this anomalous habit of serving as hosts for the particular types of bacteria that can aid them by the extraction of nitrogen from the air, it is difficult to understand. But the fact that they have developed the habit is of very great importance, because it enables these plants to enrich the nitrogen content of the soil in which they grow, instead of impoverishing it.

By turning the clover under with a plow, the farmer is enabled to restore to the soil an equivalent of the nitrogen that was taken from it in a preceding season by other crops.

The importance of this will be obvious to anyone who is aware that nitrogen is an absolute essential as a constituent of a soil on which good crops of any cultivated plant are to be grown, and who further understands that the available supply of nitrogenous salts with which a depleted soil may be restored has until recently been very limited.

Some readers may recall the prediction made not many years ago by the English chemist, Sir William Crookes, to the effect that the world would presently suffer from a nitrogen famine that would greatly reduce the wheat crop, and perhaps subject the entire race to danger of starvation. At that time the chief supply of nitrates came from the nitrate beds of Chile; and it had been estimated that in less than twenty years these beds would be exhausted.

No one then could say just how the need of the agriculturist would subsequently be met.

But the discovery that leguminous plants extract nitrogen from the air gave partial answer.

And almost simultaneously a more complete answer was supplied by scientific workers, headed by the Swedish chemist, Professor Christian Birkeland, in association with a practical engineer, Mr. S. Eyde, who discovered that it is possible to convert atmospheric nitrogen into nitric acid with the aid of electricity.

Another method of fixing atmospheric nitrogen was soon afterward developed in Italy. Thus the inexhaustible sources of the atmosphere were made available. So there is no longer any danger of a nitrogen famine, and the developer of plants no less than the consumer of plant products may look forward without apprehension, so far as the danger of the starvation of plants for lack of nitrogen is concerned.

But the mechanical processes of nitrogen fixation are necessarily expensive, and the aid of the clovers and their allies will no doubt continue to be sought for a long time to come by the agriculturist who wishes to restore nitrogen to his fields in the most economical manner.

The first crop of clover is usually cut for hay, and a second crop used to turn under in the fall to fertilize the soil. Thus this plant occupies a unique place among farm products. It not only supplies a valuable forage food, but it also helps the farmer to keep his land in a condition of perennial fertility.

There is nitrogen, worth millions of dollars, in the air over every farm in America—and by the simple process of raising inoculated legumes, we can extract and employ it—not only without expense, but at the same time producing crops of unusual profit.

A RICH FIELD FOR WORK IN THE TEXTILE PLANTS

Improving the Fibers of Flax, Hemp, and Cotton

THE cultivation of flax in America gives a very striking illustration of the extravagance of our agricultural methods.

Something like two and a quarter million acres of land are given over to the cultivation of flax, the harvested product being about twenty-five million bushels of seed. But the stalks of the plants covering this vast acreage are for the most part regarded as waste material, notwithstanding the fact that the fiber of the flax plant is everywhere recognized as the most aristocratic of vegetable textile materials.

Flax fiber, the material from which linen is made, bears somewhat the same relation to cotton fiber that silk bears to wool. Unfortunately, the plant that bears good seed does not make good fiber; although it can be used as a second quality flax, and has been used as stock for paper.

Flax in America is usually grown for the seed only, as the high cost of labor makes competition with the foreign product difficult.

Contrariwise the hemp plant (*Cannabis sativa*), a plant belonging to the mulberry family and distantly related to the hop, which resembles the flax only in the fact that it produces a tough and resistant fiber that may be used for textile purposes, is cultivated in this country exclusively for the fiber, its seed being almost altogether neglected. Yet the seed of this plant is prized in other countries for its oil, and its neglect here illustrates the same principle of wasteful use of our agricultural resources.

Hemp, however, is not very extensively grown, being chiefly confined to regions of the blue-grass country centering about Kentucky and Tennessee. Its fiber is coarse, and is used chiefly for making cordage and warp for carpets. At best the cultivation of hemp does not constitute an important industry in the general scale of American agriculture.

Cotton for Seed and Fiber

But when we turn to the third textile plant. cotton, we have to do with an industry that ranks second only to the cultivation of Indian corn.

And here there is a story of waste that assumes more significant proportions. For the cotton plant also produces seeds as well as fiber; and it is only in comparatively recent years that these seeds have been regarded as other than a waste product the handling of which gave great annoyance.

Fortunately, however, this has been changed in recent decades, and the cotton grower now understands that the seed of the plant is a product quite rivaling in importance the coveted fiber itself. Not only does the seed contain an oil that when pressed out makes a very palatable substitute for the oil of the olive, but the residue constitutes cattle food that sells for from fifteen to twenty dollars a ton—a residue that until recently was used only as fuel, until its value for starch was discovered.

So the cotton plant takes high place among producers of commercial seeds, quite aside from its significance as a producer of the most beautiful, useful, and abundant textile fibers.

In the present connection, however, it is the quality of the cotton as a producer of textiles rather than as a producer of seeds that chiefly claims attention.

The importance of the plant as a producer of fiber is too well known to require extended com-

THE FLAX PLANT

In this country, flax is grown quite extensively, but almost exclusively for the seed, the stalks being regarded as waste material. Our new giant white-seeded flax, which makes a white oil, is a wonderful improvement.

ment. Suffice it that America now produces not far from three-quarters of the world's total cotton crop, the land devoted to this crop aggregating more than twenty-five million acres, and the annual yield averaging something like twelve million bales, with a value of much more than half a billion dollars.

It is obvious that a plant that has such commercial importance is one that beckons the plant developer. For even slight improvements, when applied on so magnificent a scale, may have vast significance.

Cultivation and Improvements

Some very good work has been done in the improvement of the cotton by selection, without the aid of hybridizing.

The cotton plant came originally from the Orient, having been cultivated in India from time immemorial. It belongs to a large family that includes the hibiscus, bearing beautiful flowers, and the vegetable called, in the South, Gumbo.

The Egyptian and Peruvian cotton and Sea Island cotton falls into one group and the American upland cotton and Indian cotton into another. It is doubted, however, whether the wild prototypes of the cultivated species are known.

The newer classifications recognize twenty-four species or subspecies of cotton, including a number of American varieties that have attained great commercial importance.

The American upland cotton is a perennial plant, now cultivated as an annual, that had its original home somewhere in the heart of South America, but which has proved adapted to the climate of the North American cotton belt, and is now the chief producer of cotton in America, and hence in the world.

Sea Island cotton is a species indigenous to the West Indies. It is of larger growth than the upland cotton, attaining a height of three to eight feet, and the bolls that contain the cotton fiber are sharp-pointed and characterized by having only three instead of four or five divisions or locks. Sea Island cotton yields less fiber per acre and is more costly to pick and gin than upland cotton. But it commands a higher price. It is grown chiefly on islands, and along the coast of South Carolina and Georgia. It has peculiar value as material for the making of the foundation for automobile tires.

The Indian cotton and the Egyptian are not grown extensively in this country, although varieties have been introduced and grown by the United States Bureau of Plant Industry for experimental purposes. It is probable that these species will prove valuable when the method of hybridization is applied to the development of new races of cotton modified to meet special needs.

The cotton has a large, attractive flower, and cross-fertilization occurs to a considerable extent through the agency of bees and other insects. There is no difficulty in hybridizing different species. On the contrary, it is difficult to prevent cross-pollination where different kinds of cotton grow in the same vicinity. There is danger of contamination of the strain of any particular cotton in this way. But, on the other hand, there is always the possibility of the production of new and important varieties through such crossing.

Improvement Through Selection

Until very recently, as already intimated, the improvement in cotton has taken place almost or quite exclusively through the selection of seed, without any conscious effort on the part of the grower to predetermine the characters of the seed by cross-fertilizing the parent plants.

Indeed, until somewhat recently, cotton growers, in common with other agriculturists, have been more or less oblivious to the need of care in the selection of seed. And even now, according to so good an authority as Professor Thomas F. Hunt of the New York College of Agriculture, probably half the cotton seed planted is taken at random from the public gin. Yet the importance of selection has come to be understood in recent years by many growers, and the old slipshod methods have been abandoned by such cotton raisers as appreciate the advantages of applying scientific methods to the betterment of their crop.

The method that has produced excellent results is one that has been illustrated over and over in connection with one after another of my experiments in plant development.

It consists essentially in selecting for seed the product of plants that are observed to be more productive than their fellows, and which at the same time produce cotton fiber of superior quality.

With cotton, as with other plants, it does not at all suffice to select merely the individual bolls that chance, through some nutritional advantage, to grow to large size. It is necessary to consider the plant itself and its total product as well as the average quality of that product. We have seen that, under precisely similar conditions, different individual plants of every species show a more or less wide range of variation as to size and productivity, resistance to disease, and other qualities.

This variation is quite as notable among cotton plants even of the most fixed varieties, as among most other cultivated plants.

The practical method employed by the most intelligent cotton raisers is to send trusted employees through the fields to select the plants the product of which is to be saved for seed. The seed cotton thus obtained is ginned separately, and the owner who has taken this trouble is sure to be repaid by the improved average quality of his crop the ensuing season.

The United States Bureau of Industry has published details as to a method of selective breeding that has been practiced for several years by some growers of Sea Island cotton, through which the staple has been increased from 1.75 to 2.5 inches in length. The method requires four years of selection to secure enough seed for general planting.

The first year five or more plants are selected as the best in the field. It is urged that it is important to take the seed of at least five plants, not merely of one, because an individual plant of fine appearance may fail to transmit its characteristics. Yet my own experience with a wide range of plants would lead me to have much confidence in the progeny of the one best plant in the field.

However, the practical cotton growers have thought that they have secured better results by selecting several plants instead of depending on a single one.

The second year five hundred or more seeds are selected from each plant for the next year's planting. The second year's crop is examined with great care to see whether the desired qualities are being strongly transmitted. If such is the case, several of the best plants are again selected to furnish seed for a new planting. Meantime the seed of the remainder will suffice to plant a patch of about five acres in the third year.

The third year five hundred or more plants will be grown of each of the individual selections, and as many five-acre seed patches to produce seed for general planting as there were individuals of the first year whose progeny was considered worth propagating.

In the fourth year there will be seed for general planting from the five-acre seed patches of the previous year. There will be several five-acre seed patches from the specially selected individuals of the second year; and five hundred or more plants of each of the individual selections.

That is to say, in this fourth year we shall have a general crop of cotton plants all of which are the descendants in the third filial generation of the five plants or thereabouts selected in the first year.

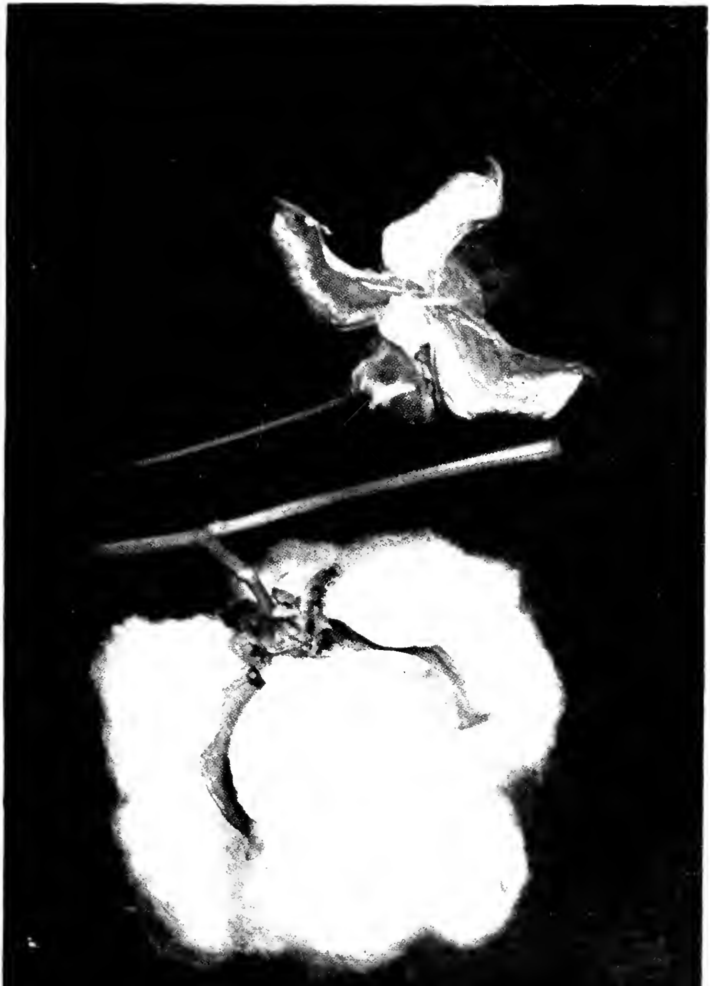
And inasmuch as each successive year the five or so best plants have been selected to start a new series, the process of betterment will go on indefinitely. The general crop in each successive year will represent the progeny, not of the crop of the preceding year, but of a third generation offshoot from the best plant of an earlier year. And the crop of this year will of course supply the five best plants to become the progenitors of the general crop four years from now.

And this, it will be obvious, is merely the applying of the familiar rules of selection which we have seen illustrated in the production of specialized races of flowers and fruits, grains, grasses, and vegetables of many types. The only difference is the practical one that, in my experiments, the inferior members of a fraternity are usually destroyed when the best half dozen have been selected for preservation, instead of being preserved for cropping purposes.

This modification obviously in nowise alters the principle, but it is a practical change that is clearly necessary to meet the needs of a cultivator

COTTON FLOWER AND SEED HEAD

The function of cotton fiber is, of course, to protect the seed and to facilitate its distribution. But nature would scarcely have carried the elaboration of the protective fiber to such a length had she not been aided by man, who has selected generation after generation among the cotton plants for the ones that produced the best quality of fiber, as gauged by his own needs.



who, while striving to improve his crop, must at the same time take such crop as can be grown year by year, without waiting for the best ultimate product.

Of course there are limits to the amount of development that is possible through such selective breeding.

The plants operated with have certain hereditary limitations, and these are pretty surely fixed by long generations of inbreeding. When these limits are attained by the practical plant developer, through the carrying out of such a system of rotation as that just outlined for a good many years, the best pure types of cotton represented in the strains under investigation will have been isolated, and the experimenter will find it difficult or impossible to make further improvement by the mere process of selection.

Then it will be necessary to introduce the method of hybridizing, to give new vigor to the plants and to produce new segregations and combinations of characters that will be equivalent to the production of new varieties. And for this purpose, as I have already suggested, the combination of strains of the American cotton with the Oriental ones, and also, doubtless, the utilization of some hitherto neglected wild species may be expected to prove of value.

A beginning is said to have been made by H. H. Webber, through combining the fine, long, strong lint of the Sea Island cotton with the large bolls and productiveness of the upland cotton.

Insect Foes of Cotton

It goes without saying that a highly specialized plant like the cotton, and in particular a plant growing in subtropical regions, is subject to the attacks of many insects.

In fact, the distinguished entomologist, Dr. L. O. Howard, enumerates no fewer than 465 species of insects that feed upon the cotton plant. But among these there are four that are so preeminent in their destructiveness as to make the ravages of the others seem insignificant. These are the cutworm (*Aletia argillacea*), the cotton worm, the cotton boll worm (*Heliothis armiger*), and the Mexican cotton boll weevil (*Anthonomus grandis*).

The cutworms are dangerous to the young plants as to other seedlings. The cotton worm may appear in hordes, but has not been especially destructive in recent years. The cotton boll worm is an insect which, notwithstanding its name, prefers other crops, in particular maize, to cotton, so that the cotton crop may be protected from its aggression by planting a few rows of maize at intervals of twenty-five cotton rows throughout the cotton field.

But the newest and most aggressive of the pests, the cotton boll weevil, is an enemy that is not so easily reckoned with.

This little insect has been known a long time in Mexico as a pest that attacks and destroys the tender portion of the cotton boll itself. But it is only in recent decades that this insect has worked its way northward and into the cotton region of the United States.

It must now be reckoned as one of the most destructive enemies of the cotton plant in the more southerly districts.

Quite recently, however, an enemy of the boll weevil has been found in Guatemala by Mr. O. F. Cook, the botanist in charge of investigations in tropical agriculture of the Bureau of Plant Industry. This enemy of the boll weevil is described as a large, red-brown, antlike insect. It is known to the native of Guatemala as the kelep; entomologists describe it as the Guatemala ant, *Ectatomma tuberculatum.*

This insect is described by Mr. Cook as strikingly adapted by structure and instinct for the work of protecting the cotton against the weevils. It has large jaws or mandibles that fit neatly about the weevil and hold it firmly, and a sting that penetrates a vulnerable point in the shelly armor of the weevil. The sting paralyzes the victim, somewhat as wasps paralyze spiders and caterpillars to supply food for their young.

After paralyzing the weevil with the poison injected by the sting, the kelep carries its prey to its subterranean nest to feed the larvæ.

The kelep does not confine its predacious attacks to the boll weevil but kills also many other insects found upon the cotton, including the larvæ of boll worms and leaf worms. It has the curious habit, Mr. Cook tells us, of storing the dismembered skeletons of captured insects in special chambers of its subterranean home.

Through Mr. Cook's efforts, this enemy of the boll weevil has been introduced. It has shown its ability to breed both in captivity and in the cotton fields of Texas. The insect forms colonies that are said to be even more highly developed than are the colonies of ordinary ants. New colonies are formed by a subdivision of the older communities, as among the honey bees, not by solitary females as is usual among ants.

It is expected that the insects will thrive in the cotton districts, and will serve at least to keep the boll weevil in check, although it is not to be hoped, according to Mr. Cook, that it will altogether banish the pest; inasmuch as the weevils have not been exterminated in Guatemala, although the kelep has there imposed a very important check on their increase.

It is urged, however, that additional protection from the boll weevil must be sought through such development of the cotton plant itself as will make it resistant to the attacks of the insect. The authorities of the Department of Agriculture have observed that in the cotton plants of Guatemala, where the weevil is native, the buds do not always drop off after being penetrated, and that the young bolls continue to develop.

It was found on examination that such resistance was due to the actual growth of new normal tissue into the cavity eaten out by the weevil larva, with the result uniformly fatal to the larva itself. It appears that the larva in its younger stages subsists entirely on the highly organized food material to be found in the pollen grains of the unopened cotton flower. The new tissue formed by a mere swelling or proliferation from the central column of the flower is watery and innutritious, and may starve the larva to death even if it does not act as a poison.

Here, then, is a method by which the cotton is able to offer effective resistance to the weevil.

It is suggested that if a variety of cotton could be developed in which the tendency to the growth or proliferation of the new tissue was pronounced, as it is in certain individuals, the weevil might be exterminated. It is considered possible that such a variety may exist at the present time in some parts of tropical America, and that if such a resistant variety can be found, it may be possible to develop the characters in the cultivated plant through selection.

Inasmuch as individual plants show this power of resistance, there should be no difficulty in developing and raising cotton plants in which this resistant quality is a uniform characteristic. The problem is obviously identical in principle with numberless other problems of plant development that have been solved in the same way.

And here, also, we may reasonably assume, aid may be secured through the careful cross-pollenizing of resistant individuals, even if no resistant species can be found with which to effect hybridization. It is reported that a tree cotton indigenous to southern Mexico is partially resistant to the weevil.

It will be of interest to determine whether the peculiar characteristic as to growth of new tissue that makes the individual cotton plants resistant to the weevil constitutes a unit character that will be transmitted along Mendelian lines, comparable therefore to immunity and susceptibility to rust as revealed in Professor Biffen's experiments with wheat.

Whether or not such is the case, it may be expected that the cotton plants that show resistance will transmit this propensity to some of their offspring. It is obvious that an investigation of the hereditary tendencies of cotton in this regard, coupled with experiments looking to the improvement of the quality of the fiber itself, should have at once a high degree of interest for the plant developer and the promise of large reward to both grower and consumer.

The geographical location of my experiment farms makes it difficult for me to experiment with so tender a plant.

But I have thought that a somewhat extended account of the work of others in the selective breeding of this plant would be of interest, partly because it suggests such close analogies with numerous experiments already detailed. I would urge upon the attention of plant experimenters who are located within the cotton belt the possibility of applying the principles that we have seen outlined in many hybridizing experiments to the improvement of a plant which, despite the excellence of its product, is by no means perfect.

The fundamental principles of plant development are everywhere the same, and the methods that have been employed at Santa Rosa to perfect flowers and orchard fruits and vegetables, grains, grasses, etc., may be applied with full confidence to improvement of the cotton plant.

In my own studies, I have come upon a variety of cotton grown in a far northern climate, that of Korea, for ages, and as it appears to be very much hardier than any cotton heretofore known, have thought it of peculiar interest. The bolls, though produced abundantly, are small and have a short staple, growing on compact, low-bushing shrubs. This matures at Santa Rosa where other cottons seldom reach even the blossoming stage.

I have sent seed of this to experimenters better located; and this unusually hardy dwarf cotton may prove of value for cross-breeding purposes.

The function of cotton fiber is, of course, to protect the seed and to facilitate its distribution. But nature would scarcely have carried the elaboration of the protective fiber to such a length, had she not been aided by man, who has selected, generation after generation, among the cotton plants, the ones that produced the best quality of fiber—as gauged by his own needs.

PLANTS WHICH YIELD USEFUL CHEMICAL SUBSTANCES

Some Observations of Sugar Cane, Hops, and Sugar Beets

An English physician residing in Trinidad made a casual observation that proved enormously important to the growers of sugar cane.

The physician observed that in the cane fields there were little grasslike plants coming up here and there. The planters whom he asked about it said that it was "grass," and let the matter go at that. But the physician had a suspicion that each blade of grass was really the shoot of a seedling sugar cane plant.

As it chanced, both the planters and the physician were right. The little shoots were young sugar cane plants; but of course sugar cane is itself a giant grass, so there was no mistake.

But the planters had not a suspicion as to what kind of grass the shoots were; so when the physician took some of them up and cultivated them, and they were seen to develop into plants of sugar cane, everyone except the physician himself was greatly surprised.

For it had been supposed that the sugar cane does not produce seed, and such a thing as a seedling sugar cane was hitherto unheard of.

The sugar cane belongs to that comparatively small company of cultivated plants that have almost totally given up the habit of seed production. We have seen that the horse-radish is another plant that has similarly stopped producing seeds, and that the common potato has almost abandoned the habit, as well as nearly all greenhouse plants which have been reproduced by cuttings or slips. Comment has been made, also, on the rather extraordinary character of this departure from the most sacred traditions of plant life.

That an organism, whose sole purpose beyond the perpetuation of its own individual existence might be said to be the production of seed, should continue to grow and thrive and yet should totally abandon the habit of seed production seems altogether anomalous.

The explanation is found, as we have seen, in the fact that man provides means for the propagation of horse-radish and sugar cane by division of roots or by cuttings. In the case of the potato, nature herself has provided tubers that take the place of seeds in a measure; and we have seen that there is a curious reciprocal relation between the formation of seeds and the formation of tubers, under certain circumstances.

In certain cases, for example, the growth of the roots of a plant or even of the plant stem may be promoted by the removal of the blossoms.

We saw also how the potato that was grafted on the stem of a tomato might grow aerial tubers from the axils of the leaves in the position that might normally be occupied by the flowers—and ultimately by seeds, had not the potato given up the habit of seed production.

Another illustration of the affinity between bulbs and flowers is shown by the onion, which sometimes grows a bulb at the top of its stalk, to perform the function of seeds in storing nutrient matter and at other times divides at the base like many other similar plants to form offshoots from which the new plant will grow another season.

But in all these cases nature is substituting one means of reproduction for another, or supplementing one means with another, and the essential purpose of race preservation is not for a moment overlooked.

SUGAR CANE TASSELS

Notwithstanding its elaborate tassel, the sugar cane ordinarily does not bear seed. Indeed, until somewhat recently, it was not known to bear seed at all. By rare exception, however, seed is occasionally formed; and the discovery that certain little grasslike plants in a sugar cane field were really seedlings of the sugar plant led to the development of a new variety with exceptional qualities. Sugar cane had been propagated by division so long that it had nearly lost the power to produce seed. The sugar cane has a plume very much like that of Pampas grass.

In the case of the sugar cane, however, it might almost be said that nature has wholly abandoned the idea of provision for the multiplication of the species, and has left the matter entirely to man. For in giving up the habit of seed production, the sugar cane has developed no complementary habit of bulb production. It is propagated by cuttings, but the agency of man is necessary to place those cuttings under proper conditions for growth.

Left to its own devices, the cane would be likely to give an illustration of race suicide.

Rejuvenation Through Seed Production

All this, however, seems out of harmony with the illustrative case with which we began.

For obviously the Trinidad physician could not have found seedlings of the sugar cane unless the sugar cane produced seed. In fact, it does produce seed *on very rare occasions,* but the habit has been so nearly abandoned that most cultivators of the plant supposed that it had been given up altogether. The Trinidad case, however, shows that nature has not altogether abandoned the sugar cane to the good graces of man. She still on occasions stimulates the plant to a revival of its long-forgotten custom. And the benefits that result from such revival will be obvious if we follow a little farther the story of the grass-like seedlings that the physician transplanted from the cane fields of Trinidad.

It appears that one of these seedlings, grown to maturity, was carried subsequently to the Hawaiian Islands, and there propagated in the usual way, so that in due course sufficient plants were grown from it to be tested as to their qualities of growth and sugar production. And it was soon discovered that this new seedling constituted virtually a new race of sugar cane; one that would grow on land so poor that it had been allowed to remain fallow.

The new variety, indeed, would produce more sugar on even the poorest land which had been abandoned than the ordinary variety produces on the best land.

Being taught by this experience, the growers of sugar cane paid heed to the seedlings in fields where they appeared, and subsequently raised from seed, and distributed in all countries new varieties of sugar cane that have probably increased the sugar production of the world by millions of tons each year.

One could not ask a better object lesson in the possibility of rejuvenating a static race of plants through the growing of seedlings.

I first made experiments with seedling sugar cane in my own greenhouses, and when reports of these were made, received letters from the various sugar-growing regions of the world, asking for further information, and now there are several well-equipped experiment stations engaged in the work of raising and testing sugar cane seedlings.

Applying the New Knowledge

The reader will at once recall the case of the Burbank potato, which is in all respects comparable. There, also, a plant that ordinarily does not produce seed was found by exception to be fertile, and the plants grown from the seed showed the widest departure from the form of the parent plant, and constituted the progenitors of a new and improved variety.

The obvious explanation is that the seeds owed their existence to the union of two plant strains, one represented by the staminate and the other by the pistillate flower, that must necessarily be somewhat divergent. The bringing together of the two racial strains results, as we have seen illustrated over and over, in the giving of renewed vigor or vitality to the offspring, and in the production of variation through the new assorting and recombination of characters, some of which may have been latent and unrevealed in one or both parents.

In the case of the sugar cane, propagation by cuttings had been the universal custom with the planters for no one knows how many generations.

As a result, a single cultivated variety of cane that chanced to be in existence when the practice of propagation by cutting was established continued unchanged as to its essential characteristics, and there was no apparent opportunity for any modification, except such minor ones as might result from increased or diminished nutrition due to the precise character of the soil and climate.

But the chance finding of the seedlings put the plant on a new basis, and gave the planters new varieties that enabled them to improve the cane, and bring it more in line of competition with the rival sugar producer that had only recently come into notice, the sugar beet.

At the time when the custom of propagating cane by cuttings was established this plant stood in a class quite by itself as a sugar producer.

But within the past fifty years the merits of the sugar beet have come to be understood. The possibility of developing a beet with a high sugar content has been established, and the beet sugar industry has risen to such proportions that it more than rivals the cane industry.

Stimulated by this unexpected competition, which threatened to annihilate the cane sugar industry, somewhat as the work of the synthetic chemist has practically annihilated indigo growing and madder growing, the planters have in recent years given serious attention to the question of the possible improvement of the sugar-producing qualities of the cane.

Many experimenters from different parts of the world have written me concerning this matter within the past twenty years. And a number of my friends and acquaintances are now raising sugar cane from seed in Mexico, the Hawaiian Islands, and Cuba, with an eye to the production of improved varieties. Their efforts should be successful.

Crossbreeding the sugar cane will give it new vitality, and careful selection from among the new varieties that will appear in the second generation should enable the cultivators to develop new strains of the sugar-bearing cane that will be far richer in their sugar content than any of the old varieties. The cane is at best handicapped in competition with the beet by the fact that it can be grown only in tropical and subtropical climates.

If it is to hold its own, it must be developed to its full possibilities of productivity.

Doubtless it will be possible to develop races of sugar cane having greatly increased size of stalk, and having also a higher percentage of sugar in a given quantity of pulp. In attempting such developments, the experimenters are merely bringing the sugar cane industry into line with the other great plant industries, most of which were neglected by the scientific plant de veloper until very recent years.

My own experiments with the cane have not extended beyond the greenhouse, but I have found that the seed germinates readily there, although only a few seeds out of a handful may grow; the contrast in this regard being very striking with the seed of the allied Pampas grass, which is as diminutive as that of the sugar cane and not dissimilar in appearance, but which germinates promptly almost to the last seed.

Allies of the Sugar Cane

I have experimented more extensively with certain relatives of the sugar cane of the tribe of sorghums.

This includes not only the sorghums that produce the sirups, but also broom corn, Kaffir corn, and a score or so of allied plants, some of which have great value as fodder plants.

The best known of the sorghums shows its relationship with the sugar cane in that it produces a sirup which, although not of the same chemical composition as cane sugar, is very sweet and palatable.

Sorghum differs very radically on the other hand from sugar cane, in that it is a hardy annual plant. It came to us from China but probably originally from South Africa, and it has proved adaptable to our soil and climate almost everywhere, and is grown in practically every State in the Union, for sirup making. It is known also as a forage plant of very great value, and its stalks supply fodder for the farm animals.

It will be gathered from this that the sorghum is a much less specialized product than the cane, and that it retains its full vigor as a seed producer.

Partly as a result of its cultivation in widely different regions of the globe, and partly no doubt through conscious and unconscious selection on the part of its cultivators, sorghum has developed many varieties, which are divided into three quite distinct groups.

VARIETIES OF SORGHUM

This hardy cousin of the sugar cane is tolerably familiar in many regions of the United States. It grows far to the North, and may be cultivated like corn. Its juices differ in chemical composition from those of the sugar cane, and its product is not susceptible of refining; but it makes an excellent sirup.

One type of sorghum is the sirup producer to which we have just referred.

The other type constitutes a very valuable forage and grain-producing plant, not altogether unlike Indian corn in general appearance, that is almost devoid of sugar.

The third type resembles the others in some respects, but the kernels are smaller and more primitive in form, the plant being used for the manufacture of brooms.

My own work with the sorghums has included many different varieties, but has chiefly concerned the nonsaccharine types, and, in particular, the one known as broom corn.

This is a variety of sorghum having long, slender panicles of a specialized form, produced by long selection for the special purpose of making brooms and brushes. The product of this plant is familiar in every household, but the plant itself has not been very generally grown in the United States until of late.

There is a vast difference in the different varieties as well as individual plants of broom corn as regards length, strength, and symmetry of the group of panicle stems, or brush as it is technically called, and equal diversity as to the quantity produced per acre.

My experimental work with the broom corn has been directed toward the development of a long, and in particular a straight, panicle stem. Most of the broom corns have long but crooked stems—that is, stems with crooks or crinkles near the base. Moreover, most of the broom corns under cultivation vary as to the quality of the brush, some of them being long, some short, and there being a corresponding diversity as to color.

I have succeeded, in a few generations of selective breeding, in greatly increasing the number of straight stems of the brush, and giving them a more shapely form. Broom corn responds readily to selection and care.

These experiments were made by selecting seed from the plant or plants in a lot that showed the best individual characteristics.

Attention was paid not merely to the brush itself, but also to the stalks of the plant. There is obvious advantage in growing a large, long brush on a dwarfed stalk, that as little plant energy as possible may be used for the production of the stalk, the chief supply being reserved for the more important brush. It was found very difficult, but not impossible, to improve the plant along both lines simultaneously, as it seemed to be working in opposite directions.

I was also able to develop a brush that had improved qualities of firmness and durability, combined with pliable texture.

The sirup-producing sorghums are chiefly of two very closely related types, which are usually spoken of as Amber and Orange sugar canes.

Individual plants vary a good deal as to their sugar content and other characteristics. My experiments with the sirup producers have shown that there is a great diversity in the individual plants as to the amount of saccharine substances in their tissues; and that it is possible by careful and systematic selection through successive generations to increase the sugar content, as has been done with the sugar beet, and is being done with the sugar cane.

This work, however, has not extended beyond the experimental stages, only satisfying myself as to the feasibility of the project; it should be carried to completion by some one working under the auspices of the Government or an agricultural society where abundant acreage and intelligent help are available.

The work is important, for the sirup-bearing sorghum is a plant of real value, and there is a great demand for its product. But the work of developing the plant does not offer commercial inducements that make it profitable for the private investigator to devote a large amount of time to it.

Some Curious Carbohydrates

The differences between the sweets extracted from the sugar cane and those taken from the sorghum are very obvious and tangible.

One plant supplies a juice that when boiled and evaporated and refined gives a fine granular product familiar to everyone as sugar.

The juice of the other plant, somewhat similarly treated, constitutes a sirup of varying color, which is exceedingly sweet and palatable, but which cannot be reduced to a granular condition in which it could by any chance be mistaken for cane sugar. Yet the chemist tells us that the sugar content of the juices of these plants is in each case a compound made up exclusively of three elements—carbon, hydrogen, and oxygen—and that the differences observed are due to modifications in the proportions in which the different elements are compounded.

It appears that sugar of the glucose type, as represented in the sirup of the sorghum, is a much more simple compound than cane sugar.

The glucose has only six atoms of carbon while cane sugar has eighteen; it has twelve atoms of hydrogen only, whereas cane sugar has thirty-two; and six atoms of oxygen, in contrast with the sixteen atoms of the cane sugar molecule.

We have elsewhere seen that starch is a compound of the same elements; differing, indeed, from glucose only in that it has ten hydrogen atoms instead of twelve, and five oxygen atoms instead of six.

Stated in chemical terms, a molecule of starch that has had a molecule of water incorporated with its substance in a chemical union, becomes a molecule of glucose; and, of course, the converse holds—a dehydrated molecule of glucose becomes a molecule of starch.

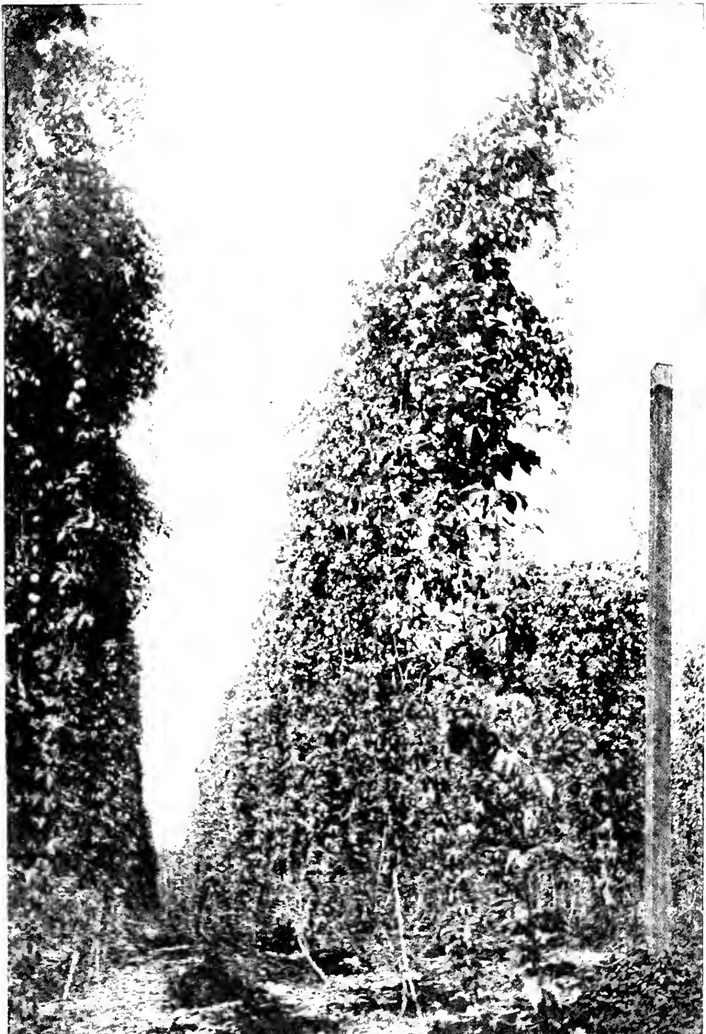
But to build up a molecule of cane sugar from either starch or glucose requires the introduction and incorporation of many individual atoms, although no new kinds of atoms are required. It is simply that the molecule of cane sugar is a very much more intricate structure, made of the same material. The glucose molecule is, if you will, a simple dwelling; the cane sugar molecule an elaborate mansion.

But the materials with which they are compounded are precisely the same.

There is a good deal of uncertainty on the part of the chemists as to the exact way in which

A HOP FIELD VISTA

This view between the rows of hop plants was taken just before the vines were let down for picking. The vines are heavily laden with flowers, and it is necessary to pick these by hand, and just at the right time. Therefore the harvest season is always a busy time in a hop region. There is no mechanical device that gives any assistance to the hand picker in gathering this crop.



the various molecules of the different sugars and allied carbohydrate substances are built up.

Some chemists regard a molecule of a substance called methyl aldehyde, which consists of a single atom each of carbon and oxygen combined with two atoms of hydrogen as the basal form of carbon compound which the chlorophyll in the plant leaf makes by bringing together an atom of carbon from the atmosphere and a molecule of water.

From this relatively simple carbon compound more elaborate compounds are built, through the introduction of varying numbers of additional atoms of carbon or hydrogen or oxygen, as the case may be, and all of the intricate juices and flavors and sweet and bitter principles of the various plants are thus compounded in the marvelous laboratory of the plant cell.

The Product of the Hop

Among the multitudes of compounds of the almost endless series in which carbon, hydrogen, and oxygen are joined through the agency of the plant cell, there is one that is of peculiar interest from the standpoint of the agriculturist, because it gives value to a plant that otherwise would be at best a troublesome weed, to be ignored and despised.

The carbon compound in question is the bitter principles known as lupulin and humulin, which are the really important constituents of the flower of the hop.

This so-called alkaloid, with its exceedingly bitter taste, would never be suspected by anyone but a chemist of having the remotest relationship with sugar; yet, in point of fact, it is made of precisely the same elements that make the sweet content of the sugar cane's delectable juices.

But the three essential elements are differently assorted, as anyone might readily surmise who contrasts the bitter taste of the hop with the sweet taste of sugar.

In fact, there are thirty-two atoms of carbon, and fifty atoms of hydrogen, with only seven atoms of oxygen making up the composition of the alkaloid that gives the hop value. No one knows precisely what is the share of each element in giving any particular quality to a plant product.

The chemist at present can only tear down the molecular structure and tell us of what it is composed.

In the presence of the elaborate carbon compounds that are represented by such substances as sugar and lupulin, he is like a barbarian standing before a beautiful temple.

The barbarian could tear down the temple, but he could not rebuild it.

Similarly the chemist can tear the carbonhydrate molecule to pieces, but he cannot put it together again. He knows how to pull to pieces the molecule of sugar, for example, making it into a simpler form of sugar, but he cannot build up even the simplest form of sugar from elementary atoms, were these ever so freely supplied him.

Carbonic acid is everywhere in the air, and water may be had for the asking.

The chemist knows just how many molecules of water he should take to combine with just so many atoms of the carbon to make a molecule of sugar or a molecule of lupulin.

But he does not know how to go about the task.

His only resort is to appeal to the agriculturist in the field, who deals with living laboratories in which the method of compounding these intricate substances is understood.

If the chemist would have sugar, he must seek it in the product of the cane or sorghum, or beet. If he would have lupulin, he must go to the hop vine, for this plant alone has learned the secret of its production.

So it chances that the ancient calling of the agriculturist is as essential to-day as it has always been; and that it is necessary to cultivate different varieties of plants in order to gain the diverse products that man needs or desires as food or as aids in the industries.

The particular product that a hop vine grows, and in the production of which it has an absolute monopoly, is used, as everyone is aware, mostly in the process of the manufacture of beer.

No product has been found that makes a satisfactory substitute for the bitter principle supplied by the lupulin of the hop.

The particular place in which the hop vine stores this bitter alkaloid, once it has manufactured it, is the curious conelike leafy seed case or envelope of the pistillate flower. Without doubt the plant develops this bitter principle and stores it there to give the seeds protection from the depredations of animals. But whatever its purpose, the bitter alkaloid provided by the hop was discovered at an early date to have value for the purposes of the brewer, and the hop vine continues to be grown in large quantities solely for the production of this alkaloid.

The hop vine belongs to that somewhat numerous tribe of plants that grow the pistillate and staminate flowers on different vines. It is only the pistillate flower that is of value to the hop grower. But a few staminate flowers are grown here and there in the field to fertilize the others, the cultivators feeling that the seed which would not otherwise be produced has at least the value of adding weight to the flower heads, and probably it adds lupulin also.

The hop has been grown from prehistoric times, and the exact country of its origin is not known, although it is found growing wild in Colorado and New Mexico in the mountains.

It goes without saying that different strains of hop vines differ in productivity, and in the amount of lupulin that their flowers secrete, and in the quality of the product. Certain Bavarian hops have lupulin of peculiarly fine flavor, but these are all less productive than the hops grown in America.

The Sugar Beet

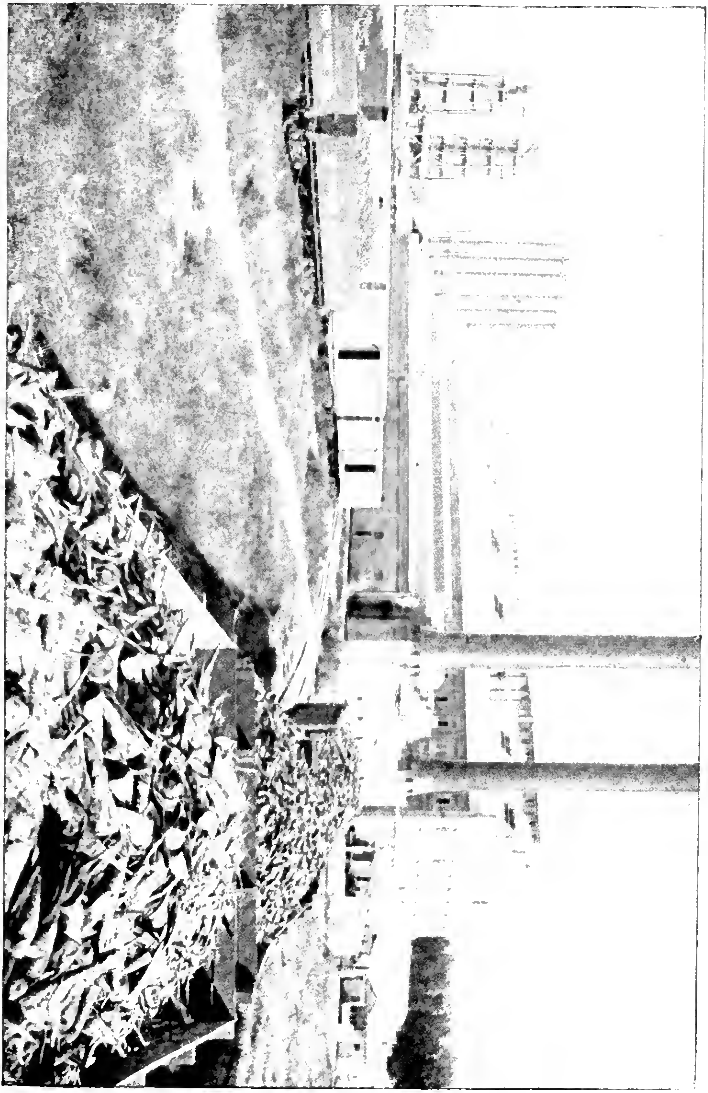
The possibilities of stimulating a plant to outdo itself in the production of its characteristic carbon compounds are well illustrated by the story of the sugar beet.

It was not much over a half century ago that the merits of this vegetable as a producer of sugar began to be seriously considered.

The fact that sugar cane grows only in warm climates, and that here is a hardy plant that may be grown anywhere within the temperate zone, stimulated the older Vilmorin brothers of Paris,

SUGAR BEETS AT THE FACTORY

Within very recent years the beet has rivaled the sugar cane as the chief source of the world's sugar supply. This would have seemed quite incredible to the chemists of a century ago, who declared it impossible to produce sugar from the beets in paying quantities. But the plant breeders of Europe solved the problem of increasing the sugar content of the beet, until now it is one of the most profitable of crops.



France, who had learned that the beet produces a sugar chemically identical with that of the sugar cane, to make inquiry as to whether it might not be possible to grow the beet on a commercial scale, and extract its sugar in competition with the product of the cane.

For a long time the attempt was not attended with great success. But it was finally demonstrated that the sugar beet, even in its then undeveloped form, could be made available as a supplier of sugar on a commercial scale, and then the attempt began to be made to develop varieties of beet having a larger sugar content.

It is said that the beets at first used contained only about six per cent of sugar.

But by most careful scientific selection through a series of generations it has proved possible to increase the sugar content of the beet, just as the length of fiber of the cotton boll was increased, merely by paying heed generation after generation to the individual plants that showed the best qualities, and saving the seed of these plants only for the raising of future crops.

Year by year the sugar content of the best varieties of beets was increased until from 6 per cent it had advanced to 20 per cent, and in the case of some individual beets even to 35 per cent; and in a few cases as high as 36 per cent has been secured from whole fields of beets in Colorado. This should be a wonderful stimulant to plant developers everywhere.

There is perhaps no other case so widely known or involving such large financial interests in which a corresponding improvement has been made in a commercial plant within recent years.

My own share in this work has been, until quite recently, that of an adviser rather than that of a direct experimenter. Some twenty-five years ago I was asked by the sugar-beet manufacturers of both Europe and America to take up the improvement of the beet. But while I gladly advised in the matter, and pointed out the lines of development through which further improvement might be expected, was unable to give personal attention to experiments with the beet, owing to the pressure of almost numberless other lines of investigation.

More recently, however, I have experimented with varieties of the beet that were already very greatly improved, working with seeds supplied by prominent beet raisers who had developed their product by combining the qualities of ten or more varieties of Russian, German, French, and English sugar beets.

The cross-breeding experiments through which I was endeavoring to increase still further the capacity of the beet for sugar were, for reasons already several times repeated, neglected.

But, so far as they progressed, they fell in line with almost numberless other series of experiments in plant development, and gave promise of the production of a beet that would have a higher sugar content than any beet hitherto under cultivation.

Just what may be the limit to the percentage of sugar that the beet can be expected to develop would be matter of mere conjecture, but that it will represent a considerable advance upon the percentage already attained is scarcely open to doubt. And even as the case stands, the sugar beet has attained a position in which it is, as we have already seen, a dangerous rival for the sugar cane.

The producers of sugar beets have been at work while the producers of sugar cane were sleeping; and the results of their efforts constitute a triumphant demonstration of the value of scientific plant experimentation as an aid to the practical agriculturist.

RECLAIMING THE DESERTS WITH CACTUS

The Methods Used to Produce a Spineless Cactus

PLAINSMEN will tell you that in the old days they have known the antelope and the buffalo to come for many miles to feast on cactus plants whose spines had been burnt off by a chance fire.

The spines of the cactus burn like tiny tapers, leaving the slabs nearly unprotected, and the succulent forage thus made accessible constituted a meal that was precisely to the liking of the antelope and the buffalo. Horses and cattle were found to relish the plant equally under the same circumstances.

In the midst of the desert sands, with little else eatable in sight that was more inviting than the sagebrush with its dry, bitter, and dusty foliage, the succulent cactus slabs, held out invitingly, offered juicy herbage that the animals browsed on with avidity.

Even when the cactus still retained its spines, the antelope would sometimes try to find a way of getting at its juicy substance. I have heard plainsmen tell of seeing the antelope holding in its mouth a slab that had been dislodged, and twisting its neck this way and that in an effort to find an unprotected spot at which it could nibble; and horses and mules sometimes persistently kick the plants in their efforts to obtain the nutritious substance of the leaves and stems.

Obviously the cactus had need of its spines if it was to escape the unwelcome attentions of the browsing animals that found such difficulty in securing sustenance among the scanty herbage of the plains and deserts.

But by the same token it appears that if a way could be found to take from the cactus its bristling array of spines, the plant might be made to supply forage in regions where other succulents cannot secure a foothold. So the problem of producing a spineless cactus was one that had but to be suggested to anyone who knew the life of the arid regions to make instant appeal.

Materials and Results

It was obvious, however, to anyone having any clear knowledge of plant development, that the task of removing the spines from the cactus would be a very arduous one.

It is true that there are small species of cactus that are spineless, or nearly so, that have been familiar for generations. One of the first pets of my childhood days was a thornless cactus, a beautiful little plant of the genus *Epiphyllum.* There are also members of the *Cereus* family that are thornless, showing not a trace of spine on any part of the plant or fruit.

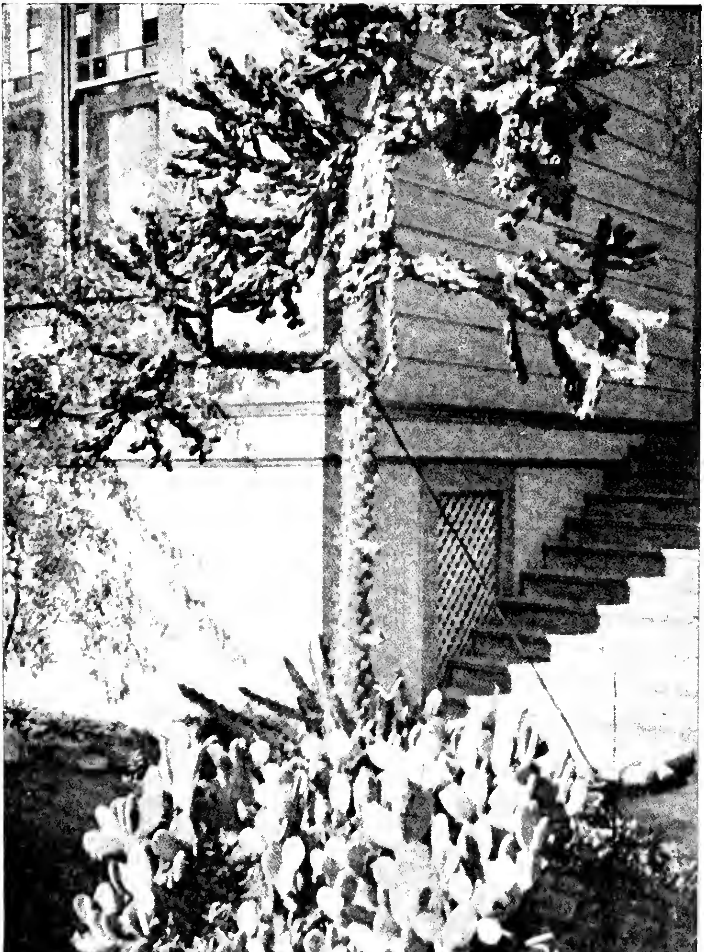
But the cactus plants that are thus unprovided with spines were without any exception small and inconspicuous species, and also with a bitter principle so disagreeable that cattle generally refused to eat them. So the plants offered no possibilities of direct development through selection that could promise the production of varieties that would have value as forage plants.

Meantime the large varieties, in particular the members of the genus *Opuntia,* which have peculiarly attractive qualities of size and succulence are thickly studded with spines for the very reason, doubtless, that were they not thus protected they could never have maintained existence in regions inhabited by the jack rabbit, antelope, and buffalo.

If the problem of securing a spineless cactus of value as a forage plant—to reclaim the deserts

THE CANDLE CACTUS

No explanation is required as to how this cactus received its popular name. It is a species often grown for ornament in regions suited to it. This is a very old specimen about fifteen feet in height. Dwarf Opuntias and various other cacti at its base.



and supply succulent food for herbivorous animals where now little but sagebrush grows—was to be solved, it would be necessary, I thought, to hybridize the already well known, partially spineless species of cactus with the large-growing, spiny ones. There seemed reason to hope that a reassortment of heriditary characters might be brought about, such as we have seen, for example, in the case of thornless blackberry and stoneless plum among other plant developments.

Thus the qualities of size and succulence of the *Opuntia* might perhaps be combined with the smooth skin of the smaller, partially spineless species.

The hope that it might be possible to effect such a transformation through hybridization was abundantly justified. In due time such a new race was developed, a gigantic cactus, overtopping all its known ancestors in size, and surpassing them all in succulence of flesh, producing fruit of unpredicted excellence in almost unbelievable quantity, and having a surface as smooth as the palm of your hand. Such a plant was produced as the result of hybridizing experiments, followed up and supplemented by the usual methods of rigid selection. But the result was not achieved with the small cacti referred to. Meantime I was carrying on extensive experiments with all the half-spineless ones which had been well known for centuries.

A Soul-Testing Experience

But the work through which this result was achieved constituted in some respects the most arduous and soul-testing experience that I have ever undergone.

In carrying out the experiments, from the initial pollenizing through stages that involved the handling of seed and the constant handling of seedlings, I was obliged to associate most intimately with the cactus plants, and it was absolutely impossible to avoid their spicules. Particularly after the work had advanced to a stage where the larger spines had been removed and the remaining spicules were in little bundles on the older joints, did it become impossible to handle them without filling one's fingers with the irritating prickles.

For five years or more the cactus-blooming season was a period of torment to me both day and night. Time and again I have declared from the bottom of my heart that I wished I had never touched the cactus to attempt to remove its spines. Looking back on the experience now, I feel that I would not have courage to renew the experiments were it necessary to go through the same ordeal again.

Not only would the little spicules find lodgment everywhere in my skin, but my clothing became filled with them, and the little barbs would gradually work their way through the cloth and into my flesh, causing intense irritation.

At first much time was devoted in the endeavor to remove the very inconspicuous but exceedingly irritating and pain-producing little spicules with the aid of a magnifying glass and forceps. But it was ultimately learned that the only satisfactory expedient was to shave off the spicules with a sharp razor, or to sandpaper them off, which can readily be done where a great quantity is to be dealt with. When thus reduced in size they would not farther enter the flesh, and gradually the pain would subside.

But the recollection of the torture in connection with the development of the spineless cactus will always remain the most painful one associated with any of my plant developments.

No other complication comparable to this has been encountered in connection with the considerably over twenty-five thousand species of plants with which I have experimented.

But possibly it will appear in the end that no other series of experiments that I have undertaken can be compared in importance to the production of the race of spineless giants which tower to almost treelike proportions, and grow with such rapidity as to produce on good agricultural land from one hundred and fifty to three hundred tons of new forage to the acre by the third season after planting, besides nearly one-third as much fruit, yet which are as tender and succulent as grass, affording forage of fine quality in unprecedented quantity, and which can send their roots far into the earth and gain a supply of water for their sustenance from subterranean sources in regions where the surface of the country is that of the desert; and economizing this for long seasons of drought which may follow.

Hereditary Traits

These new races of spineless cactus are of many varieties, in token of their varied ancestry.

In producing them I followed my usual custom of securing material from every available source.

The main supply came, naturally, from the arid regions of the Southwest, the original home of the cactus. But I received also plants from Minnesota, Montana, Dakota, New England, Missouri, and Colorado, South America, north and south Africa, and regions around the Mediterranean. It could not be known at the outset just what crosses would be most effective, and so experimented on every species on which I could lay hands. I pollenized the giant Tunas with pollen of the little trailing cactus, and with such inconspicuous cousins of the giant as the little hardy *Opuntia vulgaris.*

There were several small more or less spineless species available, and others that produced a comparatively small crop of spines, and of course it was recognized from the outset that these must be our main reliance. Just as the little French partially stoneless plum had been the foundation for building the stoneless plums and prunes of to-day, it was thought that the little cactus that was smooth-skinned might furnish the element of spinelessness in all the future races of spineless cactus, however varied the other elements of their heritage.

The most curious feature about the crossing of the giant Opuntias with the small species, in particular with the little cactus of the eastern United States known as *Opuntia vulgaris,* was that the hybrid was intermediate between the parents as to every characteristic but one. In size, stem, and manner of growth and form of

THE GRAVITY CACTUS

This new member of the spineless colony has been named the Gravity from the unusual size and weight of the slabs.

pads, it made a complete blend of the traits of the two totally dissimilar parents. But its blossom was a relatively enormous flower, very much larger than that of either parent.

As to the blend of traits of this hybrid of giant and dwarf forms of cactus, the phenomena observed were obviously comparable to those that we have seen in sundry other connections. The Primus Berry, the Sunberry, and the Plumcot will be recalled as illustrating the production of new forms, unlike either parent yet breeding true to the new type permanently even from the first generation.

The hybrid between the giant and dwarf Opuntias furnishes another illustration of the same thing. This intermediate type, strikingly dissimilar to either parent yet obviously blending the characteristics of both, bred true to form, showing nothing of that tendency to racial variation in the second generation that marks hybrids in general, and that, as will appear in a moment, marks the hybrids of the other cactuses very conspicuously.

But there is an added element of great interest in the fact that the blossoms of the new hybrid so markedly differ from the flowers of either parent and so conspicuously excel either of them in size and beauty.

It would seem that the floral envelope occupies a position in the hereditary scale somewhat different from that of the main stem of the plant. And this is perhaps not strange when we reflect that the flower is a relatively recent development in the history of plant life.

We have already noted that flowering plants are of comparatively recent origin, geologically speaking.

We have seen evidences here and there of the relative adaptability of the floral envelope as compared with the stem and leaf structure of the plant. So this new illustration of that phenomenon need not surprise us, however much it may interest us.

It would appear, if we may interpret the phenomena just presented, that the giant and dwarf Opuntias have diverged so widely that they are practically at the limits of affinity that permit crossbreeding. The stems and main structures of the plant, therefore, refuse to conform to the principles of Mendelian segregation, and hit upon a compromise in which the traits of each plant find representation.

But the flower, somewhat less fixed as to its characteristics, and indeed somewhat less widely divergent in the two species, accepts a compromise of a different order, and, under stimulus of that strange influence which we do not well understand but which we see constantly illustrated, it takes on a new vigor of growth.

It surpasses the flowers of either one of its immediate ancestors somewhat as the hybrid Royal Walnut tree surpasses its parents in growth.

This phenomenon of great vigor or tendency to excessive growth developed through hybridization, is, as we have seen, a very common one; its peculiarity in the present instance is merely that here it applies to the flower of the plant alone, whereas elsewhere we have usually seen it apply to the entire structure of the plant, including at least in some cases (for example the Primus Berry, the Phenomenal Berry, and the Royal Walnut) the fruit as well.

Let me add that when the Opuntias not quite so diverse in form as the giants and dwarfs were hybridized, the progeny showed the tendency to increased vigor of general growth, not merely to increase of the flower, although productivity was also emphasized.

Indeed, it is to the fact of such stimulus of growth by hybridization that my success in developing the gigantic races of spineless cactus is due.

Hybridizing Materials and Methods

The hand-pollenizing of the cactus, which was the foundation of these experiments in the producing of the new spineless races, presents no technical difficulties, yet requires to be carried out in a particular way.

The cactus flowers open only in the very hottest part of the day, and within fifteen minutes after the pollen bearers are exposed there is probability that the wind or bees will have accomplished self-fertilization of many of the flowers. It is necessary, therefore, for the experimenter to be on the spot, to anticipate the opening of the flower.

Our method was to collect pollen in watch crystals, and, if necessary, keep it until the flowers we wished to pollenize were matured. As the different varieties of cactus bloom at different seasons, it was sometimes necessary to keep pollen for a considerable period.

When the plant to be pollenized is ready to bloom, nothing more is necessary than to remove its stamens just before they are matured, and to dust pollen from watch crystal with a camel's-hair brush over the receptive stigma, being careful not to allow the brush to become smeared with pollen from the stamens, lest the next pollenizing be vitiated.

Each blossom thus pollenized is of course tagged to make permanent record of the cross, in accordance with the method detailed in an earlier chapter.

It was customary, wherever possible, to make the cross reciprocal, although with the Opuntias as with other plants it appears to make little if any difference as to which is the staminate and which the pistillate parent. Here as elsewhere in the plant world the factors of heredity appear as a rule to be distributed impartially between pollen grains and ovules.

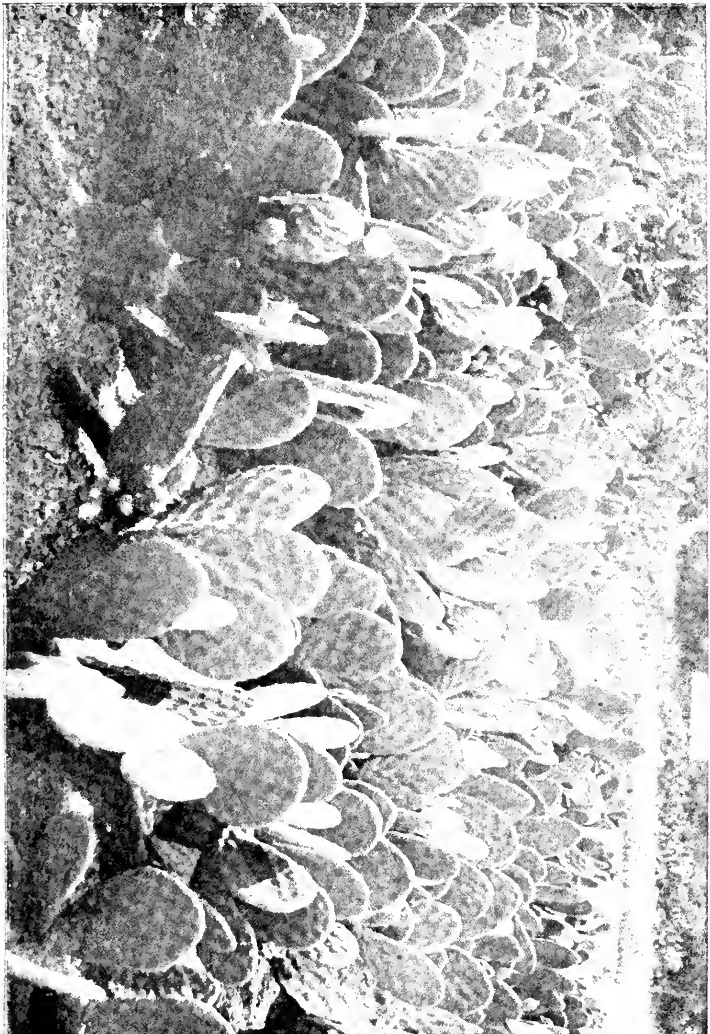
The cactus plants that served as material for my comprehensive experiments aiming at the development of a spineless race of economic value were very numerous as to species and very widely diversified as to form and habit. More than one thousand species of cactus are listed by the botanist, and there is the greatest amount of variability, so that no two botanists are agreed as to the precise classification of all the forms.

Of course I have not had every species of cactus at my disposal, but the number with which I have worked is very large indeed.

For years collectors in all parts of the world have gathered specimens for me, and, as knowl-

THE PROLIFIC CACTUS

It requires but a glance at the picture to show that this cactus deserves its name. These young plants, only a few months old, are already crowding one another and, as it were, clamoring for space. Soon they will constitute an impenetrable jungle.



edge of my work went abroad, even collectors who knew me only by reputation have sent specimens of one kind or another, until my experiment garden may be considered the great gathering place of the varied clans of the cactus family.

In addition to the specimens received from private collectors, I received also a collection that had been gathered at Washington for botanical classification. Most of these were curious thorny specimens, and I think none of them was used in my successful experiments, although all of them were carefully tested.

Some of the later acquisitions were sent by my friend, David G. Fairchild—slabs of three varieties from Sicily. I received also specimens from collectors and botanists from Mexico, South America, and Hawaii, as well as almost numberless varieties from all regions of the United States where any form of cactus grows. The so-called Smith Cactus, a variety introduced into California by Professor Emery E. Smith about forty years ago, proved of first value as a hybridizing agent.

Many Species but More Names

But it is almost impossible to gain a really accurate conception of the materials employed, because of the great confusion of the classifiers, which has led to the ascribing of different names in many cases to the same species.

For example, the variety which I received under the name "*anacantha*" (meaning "without spines") from Fairchild is identical with specimens received from the Department of Agriculture bearing only a number, and with others received from Italy on one hand, and from my collector in South America on the other, one of the numerous specimens coming under the name "*gymnocarpa*"; all of these were more or less spiny.

It was often only by careful inspection and observation under hybridizing experiments that we could identify the various specimens as being of the same species, or same variety.

Again the so-called *morada,* another species that proved of value, was first received under the name *amarillo,* meaning yellow, from near Vera Cruz, Mexico, it having been sent me by the late Walter Bryant, formerly of Santa Rosa. This I found to be practically identical with another specimen that had come from southern Europe, under the name of Malta.

Mr. Frank L. Myer, my then collector in Mexico, later employed by the United States Department of Agriculture at a better salary than I was able to furnish, sent me a variety almost or quite identical with these which he found in a private garden in Trapuato.

Another useful variety that came from various regions under different aliases was the form that has been grown in Florida and in California for the last thirty or forty years and which goes by the common name of White Fruit.

There are marked variations in the color and quality of the fruit of this cactus, the pulp sometimes being white and again variegated with yellow.

Specimens from different parts of the world might at first sight be thought to represent different species or at least different varieties; but I have found different kinds of fruit growing on contiguous branches of the same plant.

The large species of cactus that grows commonly in the Mediterranean region, known there as Indian Fig or Barbary Fig, is closely similar if not identical with the species generally called Tuna in Mexico, although the fruit of the Mexican varieties is usually somewhat smaller than that of the Old World form. The name tuna is applied indiscriminately in Mexico to cultivated and wild species of the tribe, but the varieties are sometimes recognized by different names, as Tuna Amarillo, Tuna Colorado, Tuna Blanca, etc.

Another quite common Mexican form known as Tapuna appears to be entitled to recognition as a distinct species of *Opuntia*.

It produces flat leaves that are generally circular or heart-shaped. The plant does not grow as rapidly as others of the large-fruit Opuntias, and the fruit ripens late in the season. The leaves have a somewhat white appearance, as if dusted with flour, which distinguishes them very readily from the others. The fruit is rarely edible except for stock.

The Tapuna is also of rather exceptional compactness of growth and has high nutritional value as a forage plant. Moreover it is a much hardier species than many others, resisting both cold and wet better than most of the best Opuntias.

So this species has characteristics of obvious value from the standpoint of the plant developer.

The Question of Spinelessness

But what about the matter of spines?

This, of course, from the standpoint of the present investigation, is the vital question.

The question might be answered categorically, with the statement that not a single one of the

Opuntias received from any source was altogether spineless. Spineless forms of some of the other genera are familiar, but it was early discovered that the Opuntias must be looked to for the development of a race of cactus that would have economic value. And, as I said, no form of *Opuntia* was received, among all the hundreds of specimens from various parts of the world, that was altogether spineless and spiculeless.

The form already referred to as the *anacantha,* of which specimens were received from various widely separated countries, came as near to spinelessness as any other form of true *Opuntia.*

There is a very small and very tender species that is allied to the Opuntias, and very closely resembling them, but is classified as a *Nopalia,* which was received from various parts of California and Mexico, as well as from the Hawaiian Islands, the Philippines, and from Europe, under various names, which is altogether spineless.

But this species is very sensitive to frost or to excessive heat, and in general succumbs to any untoward conditions so readily as to be valueless for this purpose, besides not being relished by any stock.

YOUNG ROYAL CACTUS PLANTS

Royal is a word that has attractive meanings when applied to plants, whatever one may think of it nowadays in its application to the human being. This name would not have been given to this particular variety of spineless cactus had it not shown altogether exceptional qualities. To casual inspection the most striking thing about it is its propensity to strike out in all directions, as if claiming all the land and air in the neighborhood as its birthright, but it is a wonderful forage producer.

We have already referred to the fact that there are absolutely spineless forms of the genera *Epiphyllum* and *Cereus*.

These, indeed, have been well known to me for fifty-five years, and are familiar to all students of plant life. But, as just noted, investigations showed that the genus *Opuntia* must be depended on for material with which to build an economic race of spineless cactus.

This experiment, it will be understood, was intensely practical in its aim from the outset.

It was not at all my thought merely to produce an interesting race of spineless cactus of diversified forms.

The spineless cactus of my ideal was one that would have practical value as a forage plant; one, therefore, that would grow luxuriantly in arid places, would be reasonably hardy and resistant to extremes of temperature, and would produce an abundance of succulent forage as well as a supply of palatable fruit.

I repeat that I have still to see any form of *Opuntia* that is of good size and suitable for forage and yet that is altogether free from spines and spicules, except the ones that have been developed on my experiment grounds, and their progeny; and no such variety has yet been reported, although the authorities of the Agricultural Department of Washington scoured the earth to find such a variety.

These, indeed, are Opuntias fulfilling every specification of spineless forage plants of reasonable hardiness, great adaptability as to soil and easy culture, and enormous productivity; and they are wonderful fruit producers as well. But they are the result of a most arduous series of experiments in plant development, and they constitute new races, entitled to the rank of new species if ordinary botanical standards are to be accepted, that have been developed here, and that, so far as there is any evidence, had never previously existed anywhere in the world.

Their descendants have gone forth to begin the reclamation of the arid places of many lands, and also to be grown with profit even in the most expensive agricultural lands, especially for feeding with other forage crops. But in no land will they come upon a cactus from any other region that closely resembles them in their combination of entire spinelessness and inviting forage qualities.

Partially Spineless Material

Yet it must be understood that the various specimens of cactus that have been sent me from all over the world, many of which were utilized in crossing and hybridizing and selective experiments, were often forwarded under the supposition that they were specimens of spineless races.

And many of them were *relatively* spineless. Some of them showed individual slabs that were almost free from spines.

But without exception these plants, notwithstanding their relative smoothness, would be found to have inconspicuous spicules or bristles, which constituted an armament almost as offensive as the larger spines; or else would soon demonstrate that their spinelessness was an individual peculiarity rather than a trait of the race to which they belonged, by developing spines on new slabs.

Yet the fact that partially thornless Opuntias exist in many regions demonstrates a tendency on the part of this plant to give up its spines partially under some circumstances.

It shows that in the heredity of the plant there are strains of spinelessness that might presumably be utilized by the plant developer in the production of a spineless race.

In particular it was learned that there is in the Hawaiian Islands cactus that develop specimens that are partially thornless when grown on mountainsides in positions absolutely inaccessible to browsing animals. Also in California, Mexico, Colorado, New Mexico, and Texas, as I learned from various reports, small patches of half thornless cactus are sometimes found, always in inaccessible crevices among the rocks. These all appear to be species of *Nopalia* and not *Opuntia*.

In some of the South Sea Islands where vegetation is abundant, and where browsing animals are few, the Opuntias have either reverted to a partially spineless condition, or have retained spines that have become merely hairlike appendages, but these are extremely tender and of no use whatever, even in subtropical climates.

This tendency to produce partially spineless races when the plant is grown under conditions that make it inaccessible to browsing animals, seems clearly to demonstrate that there are obscure factors of thornlessness in its prehistoric heredity. Our general studies in the effects of hybridizing give adequate clues as to the way in which these submerged factors may be brought to the surface.

The open secret, of course, is to blend the different strains of heredity by hybridizing the various Opuntias, and to select for propagation the seedlings that reveal the spineless condition in combination with other desired qualities.

A Spineless Race Achieved

From the outset I had been making hybridizing experiments in which I utilized in particular the hardiest races of Opuntias that could be found, choosing, of course, at the same time, those that showed a tendency to produce relatively sparse crops of spines.

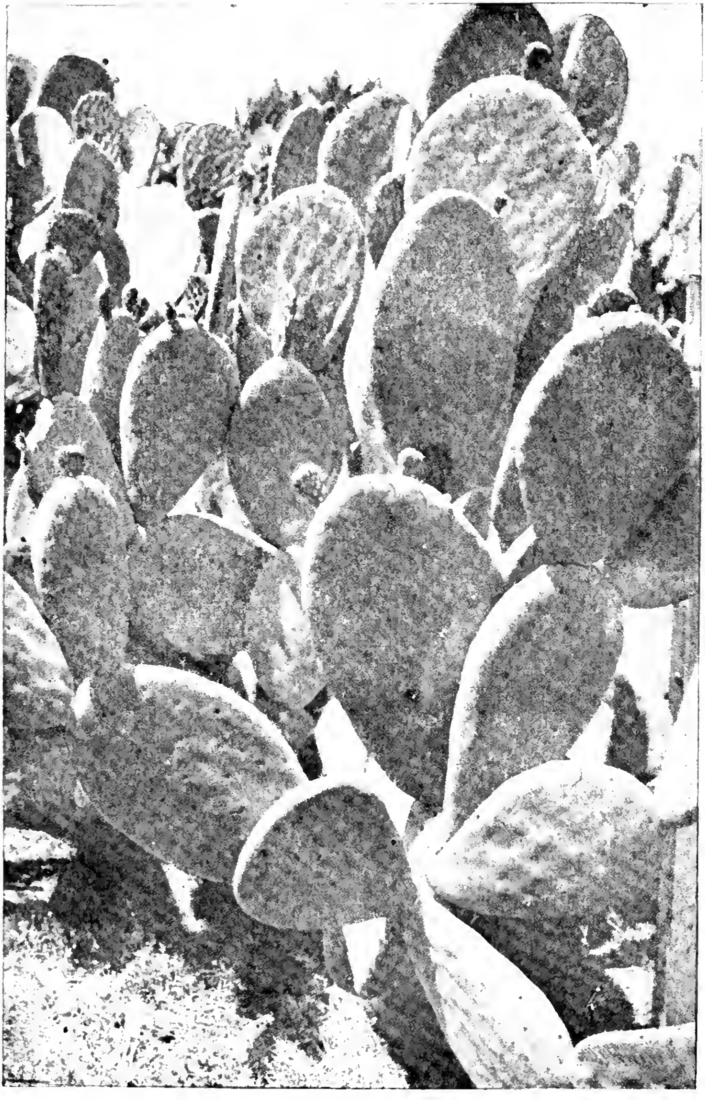
In this way I had developed races of cactus that though small in size were hardy, and that ultimately, after nine years' work, produced specimens that were absolutely free from spines. After the spines were gone, however, there remained spicules, which grow in little clusters of several hundred here and there over the surface of the joint, and which are an even greater annoyance than the larger spines to the plant experimenter, although they are sometimes ignored by browsing beasts. At the present day absolutely smooth ones have been produced on my grounds, bearing handsome fruit of excellent quality.

The hardy and partially spineless cactuses first produced were hybridized, when my more extensive experiments were under way, with the best examples of the large Opuntias received from all parts of the world.

In making these crosses I bore in mind always the condition of relative spinelessness, but also

THE HEMET CACTUS

Contrast these nearly round, flat, robust slabs with the relatively slender ones shown in some of the preceding pictures. Note that the new slabs are dimpled where the embryo leaves have been. They will be as smooth as the older slabs in due course.



the characteristics of the plant as regards size and fruit production and quality.

The precise parentage of the hybrids of the first generation was recorded, as already stated. But when the seedlings came to be handled by literal millions, and when the specimens that were utilized numbered scores of alleged species, between which it was often difficult to differentiate, it finally became impossible to attempt to follow the exact pedigrees of the selected plants, if my experiments were to be carried out on the expansive scale that was contemplated.

The seeds from different crosses were planted separately, and the character of the seedlings would reveal at an early period the quality of the plant as regards the tendency to produce spines, but not at this early stage the quality or quantity of fruit.

When the cactus seedlings first appear above ground, their cotyledons are spineless. This suggests a period when all cactus plants were without spines, for it is a familiar doctrine that the developing embryo reproduces in epitome the stages of its racial history; and the plant at the cotyledon stage may be regarded as really still an embryo, inasmuch as it is drawing its nourishment from the nutritive matter stored in the seed.

The first leaf that puts out just above the cotyledons may be spiny or hairy, in recognition of the racial period when spines were worn. But the quality of these little spicules will enable the experienced experimenter to determine whether they represent future spines or only a racial reminiscence.

So it is possible to make first selection among the seedlings at a very early period, and to weed out from among the hundreds of thousands all but a few.

Unfortunately the cactus requires from three to five years from the seed to come to fruiting time. So the experimenter who is attempting to develop an improved spineless race must wait patiently throughout this long period before he can effect a second hybridization and thus carry his plant one stage farther along the road to the coveted goal.

But by carefully selecting the seedlings that show the most likelihood of a propensity to produce smooth slabs, yet which at the same time are strong of growth and resistant to unfavorable conditions, it is possible to note marked progress even in a single generation. And when the selected plants have come to blossoming time and have been hybridized with the best among their fellows, the seedlings of this second generation will show numerous individuals that are markedly superior to their parents or their grandparents in regard to all the desired qualities.

In the second generation (we are not now speaking of the giants and dwarfs referred to earlier in the chapter) is manifested the usual tendency to recombination of the hereditary factors.

In such companies of seedlings as I developed, where hundreds of thousands of plants are grouped together, one is sure to find at least a few specimens that combine the spineless quality of one remote ancestor with the tendency to large growth of another, the fruiting capacity of a third, and so on. By attentive scrutinizing of the seedlings, at an early stage of their development, it was found possible to select thus the few individuals among the thousands that revealed the best combinations of qualities.

These are transplanted by themselves, and given every favorable condition to stimulate their growth and development, and finally placed in long rows for field culture, where they are allowed to stand for three or four years, and in the end, if one out of three hundred or four hundred is found sufficiently valuable with which to continue the work, the experiment may be considered successful thus far.

It is tedious to wait another term of years before going to the next hybridizing experiment that will give a still better crop of seedlings from which to make new selections. But of course numberless experiments with other plants are being carried out in the interval, and so the time does not seem so long while it is passing as it seems in retrospect.

Let it suffice that after fifteen years of effort, involving the collection of materials from all over the globe, the hybridizing in the aggregate of thousands of individuals, and successive selections among literal millions of seedlings, I was at last rewarded by the production not merely of one but of numerous varieties of hybrid Opuntias that grow to enormous size, producing an unbelievable quantity of succulent forage; the slabs of which are as free from spines or spicules as a watermelon; and that produce enormous quantities of delicious fruit.

Some inkling, perhaps, of the difficulties of the experiments through which this result was achieved have been revealed in the preceding pages.

Something of the economic importance of the achievement will be suggested in the pages that follow. Here let it suffice to repeat that the series of experiments in which the giant spineless fruiting Opuntias were developed was in some respects the most painful, arduous, and difficult of all my long series of plant developments; and that there is reason to believe that its results will ultimately vie with the results of any other single experiment in economic importance.

Here is a new species of spineless giant cactus which towers to almost treelike proportions, and grows with such rapidity as to produce, on good agricultural land, from one hundred and fifty to three hundred tons of forage to the acre by the third season after planting, besides nearly one-third as much fruit.

The Commercial Possibilities of Cactus as Cattle Food

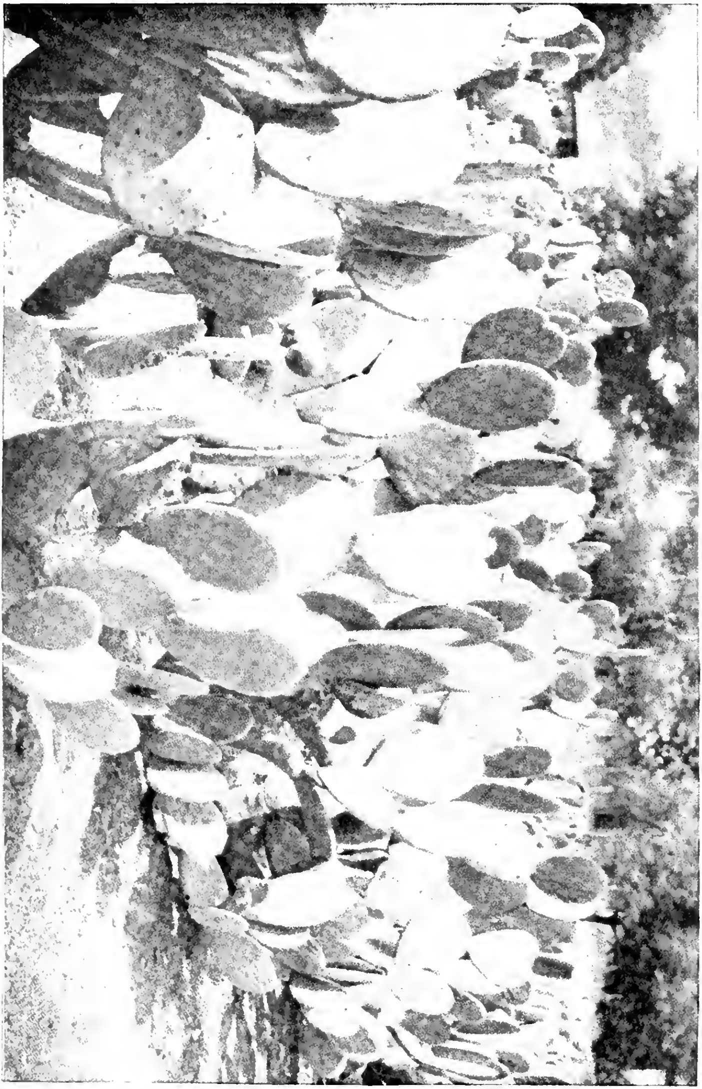
The right of introduction of certain of the first of my spineless cactus productions in the Southern Hemisphere was sold to Mr. John M. Rutland, of Australia.

Mr. Rutland had come to Santa Rosa to observe my experiments, and desired to take back with him the Spineless Cactus along with certain other of my new products, including the first of the Plumcots.

He very gladly paid one thousand dollars for a single slab of the most important of the new Opuntias, and somewhat smaller sums for slabs

THE MELROSE CACTUS

One of our improved, rapid-growing forage Opuntias just starting on their second season's growth. The fruit is hardly edible.



of several other varieties. He purchased the privilege also of introducing the new plants throughout the Southern Hemisphere.

This was the first financial return for the work on the Opuntias. It practically paid for the building of my new home, but, of course, fell far short of the sum expended on the cactus experiments.

A little later a company, formed to control the introduction of the plant in the Northern Hemisphere, paid me a large sum for my interest in the entire stock, including one or two hardy hybrids that had value for further experimental purposes. The original sale included individual slabs of the different varieties. The later deliveries included more than fifty tons of slabs and plants, constituting the tangible results of the long series of experiments.

My experiment farm, however, still has a large quantity of Opuntias in various stages of development, but particularly those that are being developed for their fruiting qualities. Not less than five hundred tons of forage—as nearly as can be estimated—are now standing on less than an acre at Santa Rosa.

As forage plants, the spineless Opuntias already developed have attained a degree of perfection that leaves little to be desired.

Propagation of the Spineless Opuntias

It should be understood that the new varieties of Opuntias, while as a whole they may be regarded as constituting a new species, are individually comparable to the different recognized varieties of any given orchard fruit, like the best apples, or pears, or plums.

That is to say, they may be indefinitely propagated by division, and all the plants grown from the original individuals will retain the essential characteristics of the original. But, like apples, pears, and plums, they cannot be depended on to transmit their best characteristics unvaryingly from the seed.

With the new Opuntias, as with the orchard fruits and so many cultivated plants, the various hereditary factors are blended in more or less unstable combinations, and this instability will be revealed in the offspring grown from the seed.

So the recognized method of propagating the Opuntias is to plant a slab, and to let this serve as the foundation from which roots and branches will grow. The slabs that develop on each plant may of course be similarly cut off and planted, so that a large territory may be rapidly covered with cactus plants, all precisely like the original.

Mention was made in a previous chapter of certain cases in which an individual cactus slab that was practically without spines might develop other slabs that would be spiny. This could only occur, however, in case the slab in question was an individual variant which owed its lack of spines to some local condition of altered nutrition.

A slab growing as a part of a plant that is spineless throughout will produce only spineless plants, with the exception of very rare bud sports which appear on all plants from time to time.

The case of the Opuntias in this regard is precisely comparable to that of the orchard trees that are propagated by grafting. In each case the entire crop of plants, although multiplied until the offshoots of a single plant may cover hundreds or thousands of acres, really constitutes essentially one plant with divided personality, rather than successive generations of plants.

Spineless Cactus from the Seed

Yet the important question has arisen as to what will take place when the transplanted Opuntias, once they have come to populate the arid places, produce fruit, and scatter their seeds. The answer is that no bad results will ensue.

The reason is that the best new hybrid Opuntias have been found to be seedless; or, where the seeds are not entirely eliminated, they are reduced in size and have lost vitality. In my experience, then, when the fruit of the improved species have ripened and dropped to the ground, under the most favorable possible circumstances, no seedlings have been seen; whereas, when the fruit of the wild ones drops there are abundant seedlings.

The case is comparable to that of the Shasta daisy, which never spreads from the seed, unlike its wild prototype. When the Shasta was first introduced, one of the Western States passed a law forbidding its growth in the State. At the present time the Shastas are grown by the millions in that State, as well as in all other regions of the world, and no one has ever complained.

With care in propagating, and reasonable protection, the new spineless Opuntias constitute a race that gives every assurance of permanency.

Yet it should not be forgotten that this race has been developed under conditions of artificial selection, and may need man's protection while it is establishing itself in any given region.

The new spineless Opuntias represent a race that has been permitted, through the fostering influence of artificial selection, to develop, notwithstanding its loss of the protective spines. Now that it has been developed, and the spineless condition combined with the traits of prolific growth and abundant bearing, the race which could never have made its way under natural conditions may be sent back to the desert to provide forage for animals in almost unbelievable quantity. But even now it will be necessary to protect the plants from the herds. It is only after the *Opuntia* has attained a fair growth that it could withstand the attacks of the herbivorous animals, which find its succulent slabs altogether to their liking.

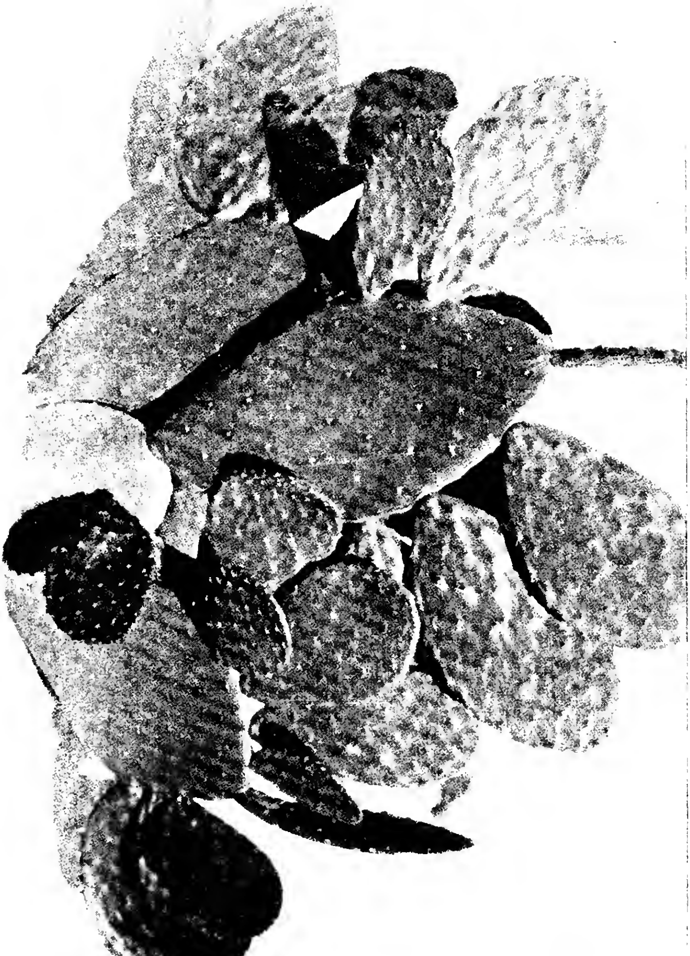
Some uninformed newspaper reporters have unfortunately given the impression to the public that the seed of the improved varieties could be sown on the desert land like wheat, and grown without fencing or other protection. Let us ask, what crop that man values in any country is not fenced? The more valuable the crop, the more carefully must it be protected. The very fact that all herbivorous animals relish these new creations proves their value and the necessity for protecting them.

Both Food and Drink

So thoroughly appealing, indeed, is the flesh of the cactus plant to the palate of the herbivo-

SPINELESS CACTUS SHOWING SIX MONTHS' GROWTH

This picture shows the rapidity of growth of some of the improved varieties of spineless cactus. The central slab originally planted has put forth several offshoots, and these, of course, have sent out numerous branches; so that now, only six months after the time of planting, the plant begins to take on the aspect of a cactus colony. Rapid growth is one of the important factors which must be constantly kept in mind in making selections, especially for forage varieties.



rous animals that many of them will feed on it even when the slabs are protected by spines.

There are regions in Mexico and Hawaii where the cattle feed habitually on wild species of Opuntias, even though this involves the habitual ingestion of millions of spines and spicules with which the slabs are protected; resulting quite often in sickness or death of the animals.

The manager of a ranch in Hawaii, writing to the editor of the "Butchers' and Stockgrowers' Journal," of California, under date of April 17, 1905, declares that on his ranch there is a paddock of 1,200 acres covered very thickly with cactus or prickly pears, with only a slight growth of Bermuda grass. In this paddock, he tells us, are pastured all the year round 400 head of cattle and about 700 hogs.

For both cattle and hogs the cactus furnishes the chief food. The hogs receive only a slight ration of corn, fed to keep them tame, and for the rest live exclusively on the young leaves and fruit of the cactus.

Both cattle and hogs thrive wonderfully. But when the cattle are killed, it is found that the walls of their first stomach are filled with myriads of small spines. The manager adds that he has never known an animal to die from the effects of these spines. This is a half dwarf, partially spineless variety, which is sometimes found in tropical islands. Yet it is obvious that the spines cannot add to the health of the creature, and it is hardly to be doubted that the animals will appreciate the giant spineless varieties when they have access to them.

But the most remarkable part of the story remains to be told.

This is the fact that the cattle have water to drink only during the rainy season, which usually includes the months of December and January. During these two months there is a certain amount of grass and they have water to drink.

But during the other ten months of the year the cattle subsist exclusively on the fruit and young leaves of the cactus.

They receive not a drop of water except as they find it in the succulent cactus slabs.

"Yet," the narrator continues, "it is a remarkable fact that during the dry months of the year we get a higher percentage of fat cattle from that paddock than from any of the others." He adds that he considers the cattle fed in this way on cactus to make as well-flavored beef as any that he has tasted in San Francisco and New Zealand.

Another record of the same sort is given by Mr. Robert Hind, a millionaire sugar planter and ranchman of Honolulu, who declares that on his ranch in Hawaii he has horses that "do not know what water is and will not drink it if it is brought before them. They have never tasted water."

"I have good, fat cattle," Mr. Hind continues, "that have never seen water and would not know how to act if water touched them. I have other cattle that I have imported from the United States which have not tasted a drop of water since being turned out on my cactus and blue grass pastures. They have lived for years without water, and are as fat as any grass-fed cattle in the United States. They make just as good beef as you can get in any restaurant."

To anyone who knows the prime necessity of a water supply for cattle and horses under ordinary conditions of grazing, such statements seem almost incredible. But they are thoroughly authenticated and, indeed, they need excite no surprise in the mind of anyone who appreciates the succulent quality of the cactus slab.

In fact, the entire cactus plant is a nutritious receptacle for holding water.

It was doubtless because the leaves of the cactus transpired water, as do all leaves, that these appendages were given up, so that the cactus of to-day is a leafless plant. A plant that grows in the desert finds it necessary to conserve water. So through natural selection the cactus developed the custom of dropping its leaves when they were only tiny bracts, at the very earliest stage of its growth, developing chlorophyll bodies in its slabs to perform the functions usually performed in the leaf of the plant.

These present a relatively small surface to the air in proportion to their bulk, and conserve in large measure the water that would be transpired from an ordinary leaf system.

This, combined with the habit of the cactus of sending its long, slender roots deep into the soil, accounts for the power of the plant to grow in arid places.

It is not that the cactus can perform its life functions without water any better than can another plant. It is only that the cactus has learned how to seek a water supply in the depths, and to conserve it after it has been found.

What the cactus does then, essentially, is to bring water from the depths of the parched earth, and to store it in its flat slabs, along with nutritious matter, so that these constitute both food and drink for the animal that eats them.

It is obvious that a plant that has such characteristics, now that it has been relieved of the spines that were hitherto its greatest drawback, and quadrupled in productiveness—with a good prospect of increasing it one thousand per cent—constitutes a forage plant that is in a class quite by itself.

The importance of this forage plant is already widely appreciated, but it will be more and more fully understood as the years go by.

Enormous Productivity of the New Opuntias

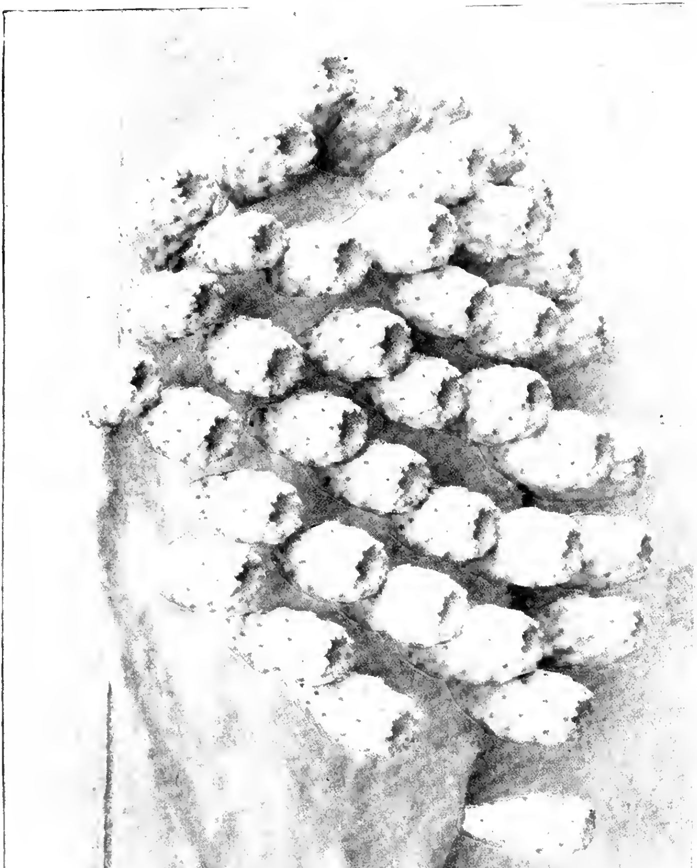
Not only is the quality of forage produced by the new species of Opuntias of a character to recommend it most highly, but the quantity of forage produced by a given acreage is altogether without precedent. Moreover, being available throughout the year in a succulent form, it is peculiarly valuable for feeding milch cows, producing a greatly increased flow of milk.

The plants grow rapidly from cuttings, and only a few months are required to produce a growth that begins to present forage possibilities.

Of course it will be better to allow the plants to grow for two or three years, and thus attain large size, before slabs are cut away. But after that the new growth may be removed from time to time as required, and the plant will be a constant forage producer for a century at least.

A FRUIT COLONY

Here are forty-three fruits on a single slab of one of my spineless cactus—one highly developed for fruiting. The slabs do not often quite duplicate this record, to be sure, but sometimes even exceed it. Thirty tons to the acre is a good yield of fruit like this.



The different varieties of new spineless Opuntias vary greatly as to size, but all are plants that on good land attain a growth of six or ten feet in height and across during a few seasons, and some of them grow much larger; a four-year-old plant often weighing half a ton or more.

There is a good deal of difference also as to size and weight of the individual pads or slabs. Many of these weigh eight or nine pounds, although the average is from two to six pounds for the improved varieties. Some of them weigh as high as eighteen to twenty-two pounds, but these are exceptional. But the varieties having largest slabs do not necessarily produce the greatest amount of food. One of the new varieties of the gigantic Tuna type has produced a slab four and one-half feet in length. This, of course, is something quite out of the ordinary; but slabs from twelve to eighteen inches in length are by no means unusual.

The growth of the plants is so prolific that the total weight of the new slabs grown in a single season, under favorable conditions, has been estimated at almost one hundred tons to the acre. On the best agricultural grounds, as on my own grounds at Santa Rosa, the plants have produced quite five hundred tons per acre in their first four years of growth. This is from some of the most highly improved varieties, on the best of land, but without irrigation or special fertilization.

Of course this growth would not be duplicated on all soils or under all conditions, but even in inferior soils the growth of the Opuntias is phenomenal, and the amount of forage produced each season is greatly in excess in weight of that produced by any other forage plant, not excepting alfalfa.

When the extraordinary weight of fruit that is borne by some varieties is further taken into consideration, it becomes evident that the new spineless Opuntia is the most productive plant ever cultivated. It is within the possibilities that a field of Opuntias, under ideal conditions of cultivation, might yield in new slabs and in fruit an aggregate edible product approximating four or five hundred tons to the acre. This has already been attained in smaller areas.

As to soil, the Opuntias grow everywhere. They may be planted on rich level land, or on the steepest and poorest rocky hillside, along old river beds, and among rock piles.

But it must not be inferred from this that the plant is oblivious to good treatment. The growth and succulence of the slabs are greatly increased by good soil. Reasonable cultivation of the soil is also of benefit, and, under semiarid conditions, a very slight irrigation once during the dry season will be highly beneficial, but not absolutely necessary, as the plants will live where not a drop of rain falls for many years, if the soil is not too fiercely sun-baked.

By such treatment the fruit is greatly increased in size and improved in quality, and the slabs for forage are doubled in weight.

In a word, no plant responds more promptly to good treatment than does the Opuntia.

Yet, on the other hand, the plant retains the primeval capacity of its ancestors to make its way under the most unfavorable conditions.

Making a Forage and Fruit Field

Unlike most other plants, the Opuntias root best during the heat of summer. This is also the best time to transplant them. In fact they should not be moved at other seasons. No one who is familiar with the Opuntias would undertake to root or transplant them during the cold, damp weather, such as would be best for other plants.

But if transplanted during May, June, July, August, or September they will thrive under almost any treatment. The joints, blossoms, buds, half-grown fruit, or any part of the plant will take root and grow under the most discouraging circumstances. I have seen them develop on the floor back of a cookstove, in the pocket of a winter overcoat, lying on a writing desk, and in similar unlikely places.

The Opuntias differ from nearly all the other plants in that cuttings must first be wilted before they will grow (unless in the dry, heated part of summer); after which nothing grows more readily.

When you receive cuttings, place them in some warm, sunny place, and allow them to remain a week or more, after which they will readily form roots and start to grow almost anywhere. They may best be planted so that about one-third of the cutting is below the soil. The cutting may be planted in an upright position, or at any angle—such details make no difference to the Opuntias.

On fairly good soil, to provide a forage field for stock feed, the giant Opuntias should be planted alternately in two rows together at intervals of three or four feet, according to variety, and then a space of ten or twelve feet left, and another pair of rows planted in the same way. This has been found to be the best way to plant the cactus, as by this arrangement space is left for general cultivation and for gathering the crop; otherwise the plants would too completely cover the ground.

The young plants must have protection from marauding beasts. Squirrels and rabbits are particularly fond of the young slabs, and in a country infested by these creatures it may be necessary to fence in a field of young cactus until it attains a considerable growth. Needless to say, it must be protected from the encroachments of farm animals, as they would destroy the young plants utterly.

When the Opuntias attain a reasonable size, it becomes, as already pointed out, a perennial source of forage. The plants live to an indefinite age, and year by year they put out new slabs, which may be cut at any season for feeding purposes.

It is best to cut the forage, and not to give the animals access to the growing plants, as in the latter case they would waste the feed and seriously injure or destroy the plants. The central stems of the old plants, however, attain a woody character that generally protects them against extermination by stock.

In practical feeding, it is desirable, where possible, to combine the *Opuntia* slabs with alfalfa, bran, and other carbonaceous and especially dry foods, like straw, hay, and the like. The *Opuntia* slabs may be fed as an exclusive diet, and in this case farm animals will have no craving for water. But in fact the cactus is not a complete feed, and it is always more economical to feed some dry food with it, alfalfa hay being one of the best, to complete and round it out as a nitrogenous diet.

Almost without exception, herbivorous animals are fond of the cactus. Cattle prefer it to almost any other food, and it makes a superior quality of beef, and exceedingly rich milk, which is not surprising considering the succulence of the cactus and the fact that it contains a relatively large percentage of the salts of sodium, potassium, and magnesium.

A very superior quality of pork is produced from pigs fed on the cactus fruit. The fruit is used also with success as a poultry food. The plant has been fed to horses, which, however, are said as a rule not to relish it until they become accustomed to it.

But the merits of the cactus as a food for animals have too long been recognized to require extended comment. The wild thorny cactus is frequently prepared for stock feeding by burning off its spines, and in Australia the leaves and fruit of the dwarf and horribly thorny kind are boiled to make them available as food for hogs, especially in long seasons of drought.

Such facts sufficiently attest the value of this plant, as well as its palatability.

The spines which have hitherto constituted the one perennial drawback having now been removed, and the plant itself having been made to reveal new capacity for growth and for the production of flesh and fruit of peculiar succulence and food value, the cactus, as represented by the new races of spineless Opuntias, must take a leading place among forage plants in all arid and semiarid districts, where the climate is semitropical.

The Cactus Produces Many More or Less Useful Substances

The chemical content of the cactus slabs depends largely on the variety and also to a certain extent upon the age of the slabs.

The young shoots in the early period of their growth have a very high water content, as is the case with all succulent herbage. The amount of crude fiber in the leaf at this stage may represent less than one per cent of the total bulk.

On the other hand, the old slabs and the main stalk of the plant take on a growing percentage of woody fiber, which renders them less and less palatable, but which adds to their value from another standpoint, as will appear presently.

CACTUS BLOSSOMS

A glance at this picture will make it clear that the cactus has full claim to consideration as an ornamental plant, and is worthy of a place in any flower garden. It has such important economic uses as a forage plant and producer of fruit that its flowering qualities are usually overlooked. But they are not likely to be overlooked by anyone who has once seen a group of the new spineless Opuntias in blossom.

The slabs during the period of their best development, when they would ordinarily be used for forage, contain, according to chemical analysis, from 2.71 per cent to 4.6 per cent of starch and its equivalent, with from .58 per cent to .72 per cent of protein, and .96 per cent to 1.68 per cent of mineral salts. There is also a very small amount of fat, which like the other nutritious elements is being increased in quantity in some of the newer varieties. The varying amount of these food constituents suggests that the quantity may be considerably increased by selection.

Of course the same thing is true of the other constituents. No doubt the protein content, for example, may be increased by selective breeding, just as we have done in the case of corn. And in general the constituents of the *Opuntia* slabs that give them food value may doubtless be increased by careful combination and selection.

Hitherto the development of the plant has been carried along the lines of spinelessness and great size and productivity; although, even as the case now stands, there has been a considerable improvement in the percentage of food constituents.

Even at the present time, however, the slabs of the Opuntias furnish fodder of highly nutritional character. That there is also a high water content is no disadvantage in a plant growing in arid regions. On the contrary, we have seen that this is to be regarded as one of the greatest merits of the plant, inasmuch as it enables animals to secure their water supply by eating the slabs, thus maintaining health and growth even when no drinking water is available for months together.

The qualities of the cactus fruit have been dealt with elsewhere.

It will be recalled that there are numerous varieties of fruit, differing almost as widely as the varieties of apples. The essential character of all the fruits of the improved varieties, however, is a peculiar juiciness of pulp, combined with individuality of flavor and in some cases a faint trace of acid. The fruit of the wild Opuntias has sometimes been characterized as lacking flavor. But constant attention has been paid to the bettering of the fruit and the fruit of the new varieties is very popular with all those who are acquainted with it.

On my grounds the choicest varieties of fruits of many kinds are grown, but the workmen usually prefer the fruit of the Opuntias to any other that is in season at the same time.

The improved fruits are also rapidly gaining in popularity in the markets. When shipped to the east they bring about the same price as the best oranges, and the fact that they can be produced at a fraction of the cost of growing the orange should give them importance from the standpoint of the orchardist.

Reference has been made also to the fact that the fruit has excellent qualities for making preserves and jams and jellies. The scarlet and crimson varieties have value in supplying color matter for other fruit preserves, ices, and confections.

This newer vegetable pigment, with its beautiful shades of color, should largely supplant the objectionable aniline dyes that are now so generally used to color ices and confections and nonalcoholic beverages.

The Food Value of the "Leaves"

In countries where the cactus grows abundantly, it has long been known that its young slabs make a palatable form of greens when cooked.

In recent years some scientific experimenters have made the attempt to test the food value of the leaves of the partially improved cactus.

The cactus leaves when fried are a substitute for some of the poorer vegetables. Tender leaves should be selected, the skin peeled off, and the plants fried rapidly in butter. Appetizing preserves may be made from the fruit, somewhat after the manner of apple butter. The fruit itself may be dried and thus preserved for winter use.

With the production of 25 to 50 tons an acre, there is opportunity to preserve the fruit on a commercial scale, if a sufficient market for it can be developed.

To me it seems that the cooked fruit lacks the fine flavor of the raw fruit. In general the fruit may perhaps be served to best advantage as a salad. But I have on several occasions had jars of delicious jams, made from cactus fruit, sent me from different localities.

The fact that the fruit of the perfected Opuntias contains a high sugar content, amounting sometimes to from 12 to 16 per cent, makes it obvious that this plant might be used for the production of methyl alcohol. The slabs may be used for the same purpose, and the enormous productivity of the plant would make amends for the comparatively low percentage of fermentable starch in the composition of the slabs.

As a Famine Preventer

It has been estimated that the improved Opuntias produce foliage and fruit so abundantly that they could be grown advantageously on land that cost even one thousand dollars an acre.

Analyses made by the Agricultural Department of the State University of California have shown that the new varieties greatly exceed the old ones in nutritive qualities. Yet even the undeveloped Opuntias have long been recognized, particularly by the peoples of the Mediterranean as having high food value.

The importance of the new plants as suppliers of food for human beings, in regions subject to occasional or habitual shortage, has been recognized by several governments.

The German Government before the World War was testing these new Opuntias at several places in its possessions in Africa.

In parts of India where famines threaten and from time to time destroy millions of people, my new spineless cactus is being planted for the purpose of tiding the people over in the years of famine, even if not used as a part of the regular dietary.

The plants have been introduced to Australia. They are also being tested in Brazil, Argentina, Paraguay, Chile, Peru, and in other parts of South and Central America and Mexico.

The new Opuntias differ from almost every other plant, and may be said in a way to resemble canned food, in that their food content remains in perfect condition on the plants year after year until needed. Nothing more is required than to plant the Opuntias, and fence them against the encroachment of animals. It is not necessary to cultivate them, although it is advantageous during the first two or three years, nor need any attention be paid them until their slabs are needed.

They would thus grow enormously and when the occasion arose they would supply an almost indefinite quantity of food to meet the needs of a population that otherwise must die of starvation.

The value of a plant that need not be cultivated and needs no preparation yet which will perpetually hold in reserve a colossal quantity of food per acre, constantly adding to it (the annual increase being measured in scores of tons), offers a refuge to populations that are threatened with years of drought and failure of cereal crops that is not duplicated by any other food produced hitherto under cultivation.

Even if the new spineless Opuntias had no other function than this, the time and labor devoted to their production would obviously be repaid a millionfold.

Important By-Products

There is one curious property of the slabs of the Opuntias that to some extent militates against their popularity as foodstuffs. This is the fact that the leaves contain a mucilaginous substance, the quantity of which, however, varies widely with the different varieties.

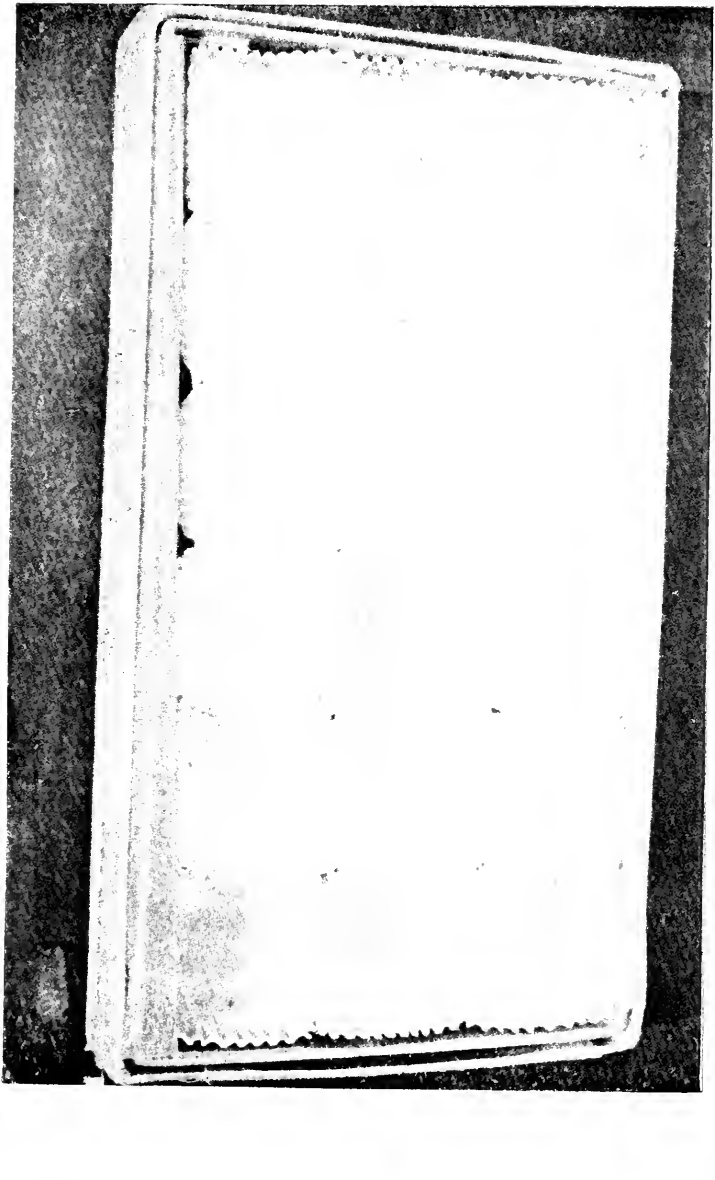
The varieties that contain less of the mucilage are used by the Mexicans for the making of confectionery. Some of the finest confections of Mexico are canned cactus leaves.

The leaves also make excellent pickles, the only drawback to which is the presence of the mucilage in the case of some varieties. Those that lack the mucilage make pickles as fine in flavor as the best cucumber pickles.

On the other hand, the mucilage, while undesirable from one standpoint, is not without its value. It may be extracted by cutting the leaves in thin slices, and placing them in water. One or two slabs will make a gallon of good, thick, perfectly transparent mucilage. When this substance dries slowly, it produces a gum

CACTUS CANDY

Here is a tray of delicious candy made from the cactus. The Mexicans have long been accustomed to make various confections from the wild ones. With the new fruiting varieties, with their greatly enhanced crops now available, it may be expected that cactus candy will gain in popularity. No confectionery can surpass well-made cactus candy.



that is generally white or of a pearly color, and not easily dissolved in water.

The mucilage is often used locally to mix with whitewash, to which it gives something of the permanency of a paint. It is also used at times for stiffening sleazy cotton goods, and for water-proofing cloth.

Beyond this the economic uses of mucilage have not been developed. But sooner or later some one will find use for this by-product of the cactus, for the dressing on a large scale of fabrics, or any one of the hundred purposes to which mucilaginous substances are put. I have made many tentative experiments to test the qualities of the mucilage, but these have not been carried far enough to produce conclusive results.

The Opuntias have possibilities of a quite different character, connected not with their juices, or pulp, but with the woody fiber which makes a network in the older leaves and which comes to form the main substances of the central stalk.

It has been found that this woody network, when the pulp is removed, makes a clean white fiber that is in the most beautiful condition for paper making. The older stems and roots furnish the fiber in considerable quantities, and even the roots are available for the purpose. The amount of paper stock varies much in the different species. The expert estimate of the fiber as a stock for the making of the finest paper, including banknote paper, has been so enthusiastic that it might be well to devote attention to the breeding of some of the spineless Opuntias with an eye to the development of the fiber, so that this by-product of the plant may become of value as a source of paper stock; also for the making of leather board.

One striking peculiarity of the *Opuntia* fiber is that it is bleached without any preparation. When the pulp is removed, the remaining fiber is white, and ready for use without necessitating the usual process of bleaching.

So the *Opuntia* which develops its enormous weight or tonnage of forage and its abundant supply of food for man in the early stages of its growth, will subsequently, without relinquishing its original function, produce supplies of fiber that may be of value. The rapidity and growth of the plant would insure the production of such quantities of material as to give it a certain importance even if it could be grown only on arable lands; but the quantity is at best relatively small. That it can be grown also on many otherwise waste places is obviously an additional merit of the first grade.

A Summary of Qualities

Let us, then, in conclusion, summarize briefly the qualities that give the new spineless Opuntias economic value. In so doing I may refer to two or three subordinate uses to which the plants have been put that have not been specifically mentioned in the preceding studies. Here is the list:

First: The new spineless Opuntias supply abundant quantities of fresh fruit that is unique in form and color, of superior flavor, of sure crop, and of good shipping qualities. Delicious jams, jellies, and sirups may be made from the fruits; and its juices are used for coloring ices, jellies, and confectionery.

Second: The slabs or so-called leaves of the plant supply an unprecedented amount of forage for stock of all kinds and for poultry.

Third: The young slabs make excellent pickles, and are good and wholesome food when fried like egg plant. They are also boiled and used as greens, and may be prepared with sugar to produce a sweetmeat similar to preserved citron.

Fourth: The leaves are extensively used in Mexico and elsewhere for poultices, and as a substitute for hot water bags—the thornless kind being naturally preferred!

Fifth: The abundant plant juices contain a mucilaginous substance that is used to fix pigments, and which in time will be put to many other important uses.

Sixth: The thorny varieties are used for hedges or fences, as well as for ornament, and even to protect the thornless ones. No animal of any kind will undertake to pass through one of these thorny hedges. In regions subject to the drifting of sand they serve an important purpose as barriers.

Seventh: The fiber of the plant makes an admirable stock for the manufacture of paper, but not as yet in large quantities.

Eighth: In general, the adaptability of the new Opuntias to the arid region gives assurance that vast semiarid regions of the globe will be made habitable and productive, although hitherto they have produced scant if any vegetation of economic value.

Without looking further it must be clear that a plant having such qualities may be regarded as the most neglected of vegetable products. Owing to its spines, the cactus has been regarded as an enemy of man. Now that its spines are removed its good qualities will in due course be appreciated. Should their present promise be fulfilled, the giant spineless Opuntias may make vast areas that heretofore have been relatively sterile among the productive regions of the world.

They may supply fodder for unlimited numbers of cattle, that will give cheaper food to the masses, and conspicuously decrease the cost of living.

They may even avert famines in regions that have hitherto accepted the recurrence of starvation years as an inevitable visitation.

And even should the future benefits that accrue from the new spineless Opuntias realize but a fraction of their present promise, these plants might still be entitled to a foremost place among the forms of vegetable life that have been introduced, or improved, for the service of man within the historical period.

The Heredity of Spinelessness

Before taking leave of the spineless cactus, it may be of interest to make further inquiry as to the hereditary bearings of the condition of spinelessness.

We have seen that the new spineless Opuntias were developed by a long series of experiments in hybridizing and selection, in which use was made of individuals that showed a propensity to depart from the spine-bearing custom of their race. Among the seedlings of these plants some were found to be much less spiny than others, and it was ultimately possible, by selecting among literal millions of specimens, to develop races absolutely devoid of spines and spicules, as we have seen.

It would not have been unreasonable, perhaps, to expect that the spineless races thus developed would breed true to spinelessness; particularly when we recall that the thornless blackberry, if inbred, produces only thornless progeny. But if such an expectation were entertained, it would be doomed to disappointment, for the spineless cactus does not breed true. In point of fact, there may be found among the seedlings of a spineless variety plants that fairly bristle with spines, rivaling in this regard the best protected of their wild ancestors.

Obviously, then, the condition of spinelessness in the cactus has quite different relations in the scheme of heredity from the conditions that govern spinelessness in the blackberry. In the latter case, as we have seen, the spineless condition appears to be recessive, and the thornless individual is as free from tendency to produce thorns as if its entire coterie of ancestors had been perfectly smooth-stemmed. The individual spineless cactus, on the other hand, retains the factors for spines in its germ plasm, to make their influence tangibly felt in a large proportion of the offspring.

Nevertheless, it does not appear that the condition of spininess acts as a simple Mendelian dominant. On the contrary, it appears that the hereditary conditions that govern the spiny condition in the cactus are very complex. The best interpretation would seem to be that there are multitudes of factors for spicules and spines, variously blended in the germ plasm of any given individual. The spiny condition, on the whole, tends to be dominant to the spineless condition, because the spines are a relatively late development in the history of the evolution of the cactus tribe.

But doubtless the period in question was an exceedingly long one, covering many thousands of cactus generations, during which the plants were becoming better and better protected; and each stage of such development may be thought of as having its hereditary factors in the germ plasm, capable of acting independently.

Thus it is that in the same fraternity some seedlings are exceedingly spiny, while others have a comparatively small number of spines, and a few may be absolutely spineless. Thus, also, is

A CACTUS-SLAB FAN

The fibrous portion of this fan represents the fiber of a cactus leaf from which the pulp has been removed. In the young slab, these fibers are tender and fragile, but they become tense and rigid in the old slabs. An excellent paper may be made from this fiber, and it will doubtless, in time, be put to many other economic uses.

explained the fact, to which attention has been called, that the plants that are altogether spineless may still be provided with minute spicules. Such minute spicules were, perhaps, the first defensive mechanism to be developed in the evolution of the cactus tribe, and they have back of them such numberless generations of heredity that they hold their own with exceptional persistency.

In dealing with the spines and spicules of the cactus, then, we must consider that we have to do not with a single hereditary factor or two, but with a multitude of factors. Now our earlier studies have taught us that where several or many hereditary factors are in question, the probability that they will all be combined in any given way in a single individual decreases at a geometrical ratio. We found, for example, that where ten hereditary factors were under consideration, the probability of their combination in a predicted manner was only one in something over a million. In the case of the cactus the factors for spininess doubtless number far more than ten; from which it follows that the probability that any given seedling will have germ plasm absolutely free from any of the factors for spininess is much less than one in a million.

This explains why it was necessary, in our experiments at Santa Rosa, to plant the seeds by literal millions, and to select persistently among uncomputed multitudes of seedlings.

Fortunately the spiny condition reveals itself almost from the outset, so that it was possible to weed out the vast majority of all the seedlings, retaining only, perhaps, a stray dozen or so from among the legions.

As the experiment proceeded, however, it was gratifying to note that in succeeding generations there was an ever-increasing proportion of spineless seedlings. This suggests that some of the factors for spininess were being dropped out of the heredity of the selected plants.

Obviously this seems to augur that should the experiment be carried forward through a sufficient number of generations, the time will probably come when all factors for spininess will have been eliminated from the germ plasm of the selected opuntias; in which case they will then breed true to spinelessness from the seed.

This prediction finds further warrant in the fact that the newest races of spineless opuntias show a far more pronounced abhorrence—if the phrase be permitted—of the spiny conditions than did the earlier ones. It was observed that the first spineless opuntias to be developed at Santa Rosa, although remaining perfectly smooth under ordinary conditions of cultivation, had, nevertheless, a tendency to revert to the spiny condition if placed under disadvantageous conditions—say in arid soils, unwatered and uncultivated; a state comparable to that of the wild spiny progenitors.

This tendency to reversion is in itself highly interesting from the standpoint of the student of heredity; being comparable, perhaps, to the observed tendency of some plants, on rare occasions, to form what are termed bud sports. As a rule, plants grown from cuttings or roots or buds reproduce absolutely the characteristics of the parent form. We have seen this illustrated over and over in endless numbers of cases, from orchard fruits to Shasta daisies. This rule holds true of the cactus, as has been pointed out in recent chapters. You may produce an entire field of spineless opuntias of any given type, as offshoots of a single slab.

But of course no plant is free from the power of environment, and no one needs to be told that the choicest orchard fruits, for example, will fail signally to justify expectations based on observations of their parent forms, unless they are given proper conditions of soil and cultivation. Cuttings or buds of the Baldwin apple, for example, will produce but perverted replicas of the original Baldwin if grown in an arid soil, deprived of moisture, and shaded by other trees. Under such conditions, the choicest varieties of apples tend to revert more or less to the primitive type of the wild ancestor of very remote generations.

Similarly the spineless *Opuntia* may tend to revert to the wild forms if placed under primeval conditions. In a stony, arid soil, deprived of moisture, it may not only be stunted in growth, but it may show a propensity to revert to the spiny condition. Such, at any rate, was the case with the earliest spineless opuntias that were produced at Santa Rosa, but this tendency is wholly obviated in the newer ones.

As the experiment has gone forward, however, the condition of spininess has been more and more subordinated, as just related; the proof being not only that the individual plants are absolutely free from spines and spicules, but that more and more of their seedlings are found to be spineless. And this elimination of the hereditary factors for spininess is so profound and deep-seated that the newer or more recently developed varieties of spineless opuntias appear to have lost altogether under all circumstances the capacity to revert to the spiny condition. Even under the most adverse conditions of soil and climate, they remain absolutely smooth. One other step of progress and, we may confidently predict, the factors for spininess will be so completely eliminated from the germ plasm that the spineless opuntias will breed true from the seeds.

Even then it must not be expected that the seedlings in any given case will reproduce all the good qualities of the parents; any more than the seedlings of cultivated varieties of apple or pear or peach will duplicate the qualities of their parents. We have seen that the seedlings of the thornless blackberry are not precisely like the parent form. But they all are thornless. Such will be the case, ultimately, with the spineless opuntias.

And it must be obvious that when this condition is attained, the experiment of developing the opuntias in any direction will be greatly facilitated. With many varieties of spineless opuntias in hand, each one absolutely free from the tendency to revert to the spiny condition, we shall be able to carry forward experiments in crossbreeding and selection through which any desired quality may be accentuated and developed.

At the present time, for example, the spineless opuntias are somewhat lacking in protein content. Their foliage value is not quite what it would be if the protein content could be increased. And there is no reason to doubt that such increase may be possible through selective breeding. Already the developed spineless opuntias exceed all other plants in their capacity to produce an enormous quantity of forage. Through selective breeding their preeminence may be still further advanced in that each individual slab may be given enhanced food value. And the qualities of other useful chemical substances in the cactus may similarly be increased in selective varieties.

Heretofore the development of the cactus has been along the lines of spinelessness, size, and productivity; the future will see a marked improvement in the percentage of its food constituents, especially in its fruits.

OTHER USEFUL PLANTS WHICH WILL REPAY EXPERIMENT

Transformations and Improvements Waiting to Be Made

A STORY is told that, if true, gives a former Mikado of Japan an important place among plant developers.

The Mikado, so the story runs, was riding about the country—as was once the custom—to inspect the crops, and he espied a bunch of rice which seemed to be earlier and more productive than others in the same field.

Evidently aware of one of the fundamental principles of plant breeding, the Mikado directed that the seed from this hill of rice should be carefully preserved and sown by itself the next season. From this seed, if we are to believe the legend, a superior new variety of rice was produced in Japan.

Whatever the authenticity of the story, the fact that it is told gives evidence that some of the fundamental principles of improvement of plants by selection are widely recognized in the land of the Mikado.

But this, indeed, is a proposition that scarcely needs demonstrating, considering the curious variety of flowers and fruits that have been developed there. That the revered name of the Mikado should be associated in popular legend with the perfecting of the rice is to be interpreted, I suppose, as an evidence of the importance of this grain to the people of Japan, rather than in any literal sense.

Rice is to the Oriental people what wheat is to the people of the western world, and it is natural that folklore should associate the perfecting of this most important of foodstuffs with the most sacred office of the ruler who is regarded as the Father of his people.

Rice and Its Improvement

Mention of the perfecting of special varieties of rice implies the existence of different varieties of this grain.

In fact, rice is a very variable plant, and one that is therefore susceptible of great improvement. There are many varieties of rice grown in the Orient. There is, for example, a variety that has a very pleasant aroma when cooked.

There are varieties that grow on the upland, the culture of which is similar to that of wheat or barley; notwithstanding the fact that rice is usually thought of and grown as a marsh plant. These have recently been introduced into the cotton regions of the south, and I am told that in some regions they are supplanting the cotton crop. Also rice in certain sections of northern California is lately being grown by the million bushels annually.

Some botanists have classified no fewer than six species of rice, and there are many hundreds of varieties, variation seeming to be no more unusual than with wheat, oats, or barley. It is only the relative unfamiliarity with rice of the western world that has led to the supposition that one kind of rice is like another. At the Panama-Pacific Exposition of 1915 over two hundred varieties were on exhibition from the Philippines alone.

Our estimate of the grain is somewhat analogous to our estimate of the Oriental peoples.

The casual western observer thinks that all Japanese and all Chinamen look a good deal alike; but to the practiced eye there is nearly as great diversity among them as among European races.

The upland rices show their derivation by requiring somewhat moist soil, and they are not grown to advantage in California, except in the moist retentive soils of the Sacramento Valley, and to a certain extent in the Coachella Valley. In the former region, however, the growth of the upland rice has proved to be exceedingly profitable.

I have tested different kinds of rice here on several occasions, but the results were not such as to induce me to continue its culture, the conditions not being favorable.

But the fact that varieties of rice have been developed that grow on the upland gives assurance that further development may be possible in the direction of adapting the plant to general cultivation on lands suitable for growing of other cereals, as already demonstrated in the South. Doubtless a good deal can be done also to make rice a hardier plant through selective breeding; and few attempts at plant development could have greater importance, for rice is a grain hardly inferior to wheat itself in nutritional value, and one that might be cultivated far more extensively in this country, to very great advantage.

My own experiments have had in view the possibility of the development of the American wild rice (*Zizania aquatica*) of the northern lake regions. This, however, is not a true rice, being classified as *Zizania,* while rice belongs to the genus *Oryza.* Some twenty years ago I desired to undertake such an experiment, and sent to many places in the United States to get seed of the best varieties. But although I secured seed of the wild rice, my experiment, I regret to say never got beyond the preliminary stages, because the seed would never germinate.

After testing it in successive years I was convinced that the seed of the wild rice must be gathered fresh for planting. For its improvement it would be necessary for men with boats to watch individual plants, and gather seed for immediate planting.

The fact that the plant grows in the water accounts, no doubt, for this unusual quality of the seed, as it will not germinate after once being dried like other grains. It grows always in standing water, and is generally collected by the Indians, who are extremely fond of it. They go out in canoes when the wild rice is ripe, and bending the rice over their canoes thresh it from the heads into the boat. During the last year a well-known San Francisco grain firm had collected some of the wild rice and kept it moist, and they expect to make a successful introduction of it in this State. Conceivably a commercial variety of importance might be developed that would be better adapted to the American climate than the oriental rice.

I hope even yet to be able to make the experiment. Failing this, I trust that some one else will take the matter in hand.

Some Neglected Grasses

If my work with rice has been only tentative, there are almost numberless allied grasses with which I have experimented on a comprehensive scale.

Indeed, I have raised, at one time or another during the past forty years, almost every grass that has economic importance, and many never supposed to have value. Among these several fine varieties have been introduced through Cecil Rhodes of South Africa, which proved enormous croppers in moist, warm regions of this State. Some of these I have grown extensively year after year; others only for a single season, for the purpose of obtaining variation in some useful direction.

My work with the familiar giant grasses, Indian corn, sorghum, and teosinte, and with the equally familiar small grains, has already been detailed. I refer here to other grasses that are less widely known to the general public, including some that are rarely seen even by the agriculturist.

My experimental work with these various grasses has been as diverse as the qualities of the plants themselves.

In some cases I have selected for increase of productivity, and in others for increase of chemical constituents, or for beauty of plume, or ability to resist drought or frost or wind or moisture; or, again, for compact growing or for ability to spread, or for length and breadth of leaves, or for striping of foliage.

The grasses are so numerous and so diversified that there is opportunity for almost indefinite choice as to lines of development, and there are few other groups of plants that offer greater possibilities.

To casual inspection, to be sure, most of the grasses seem rather uniform, commonplace, or unattractive. They lack the beautiful flowers that so many other plants present, and their forms, if almost universally graceful, are for the most part lacking in picturesqueness. Add that the grasses present great difficulties to the botanical student because of the minuteness of their flowers and the vast number of species more or less closely related, and you may readily understand why this tribe of plants is so commonly neglected by the amateur.

But when we reflect that the family includes the most important producers of food for man and animals; and when we further reflect that there are doubtless many species still undeveloped that might be brought into the company of economic plants, along with wheat, oats, rye, corn, and rice, it is evident that the grasses should be second to no other form of vegetation in their interest for the plant developer.

Nor will the plants themselves be found to lack interest when once their acquaintance is made in the right way.

They vary in size from tiny sprigs of vegetation to the giant pampas grasses, and to bamboos two hundred feet in height and six inches in diameter. We have already seen that their products comprise not merely universal food and forage for domestic animals, and grains of inestimable value, but juices (in the case of cane and sorghum) that are second in importance only to the grains themselves.

We saw too that there are minor products, such as the panicle of the broom corn, that have no small measure of usefulness. And it is known to everyone that the stalks and straws of the various grasses have a wide range of utility in the manufacture of numerous articles of everyday use, including the mats beneath our feet and the hats on our heads, as well as the food from the tubers of the nut grass.

Whereas it cannot be said that a family of plants that is thus comprehensively in the service of man—having had, indeed, a most important share in the development of civilization—has failed of recognition, yet it remains true that there are perhaps thousands of grasses that are almost surely susceptible of great improvement, from the human standpoint, to which very little attention has been given by the plant developer.

These present an inviting field for further development.

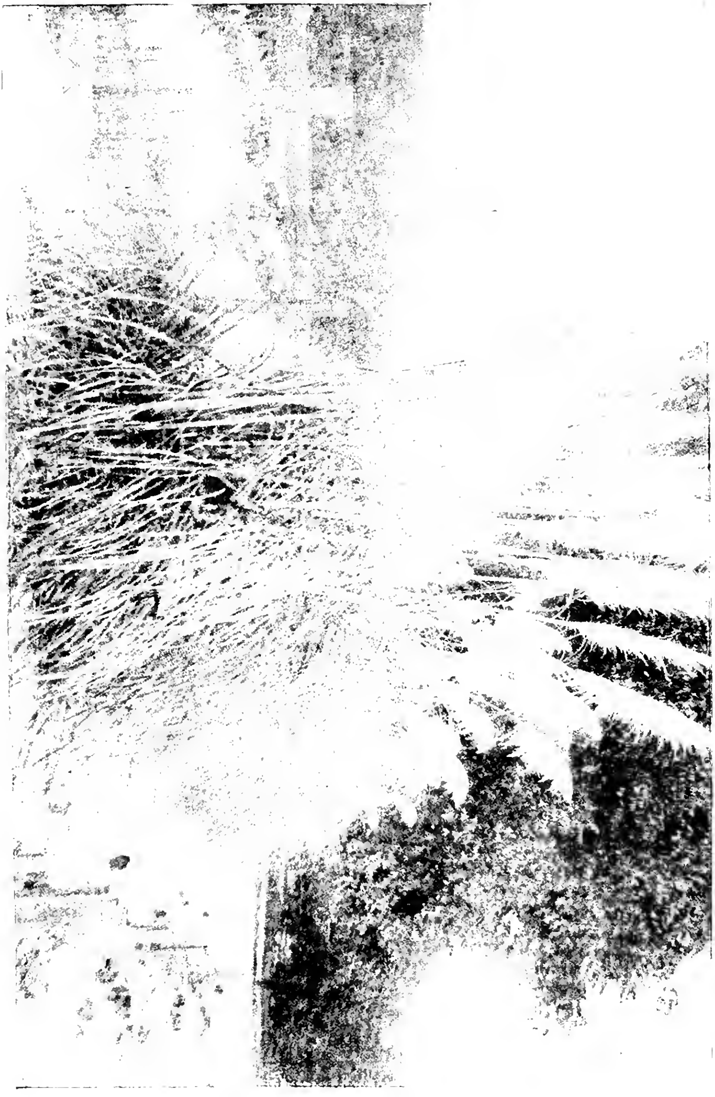
I shall offer in the succeeding pages suggestions as to a few of them, drawn from my own experiences. To attempt to deal with all the neglected grasses comprehensively, and to point out every individual possibility of useful development, would require volumes rather than paragraphs.

A New Bread-Making Possibility

One of the grasses upon which I worked for several years was what is known in the catalogues as "Idaho brome grass," classified as *Bromus inermis*, or *Bromus giganteus*.

PAMPAS GRASS

I have experimented very extensively with various types of pampas grass, developing some interesting varieties by hybridization and selection. The pampas grasses are not as popular now as they were a few years ago, but they are no less beautiful than they were when they had their heyday of popularity.



I chose this plant on account of its extreme hardiness. It resists drought remarkably, and is very productive. My original seed was received from Montana. I have also grown extensively other species of the same genus, to the number of four or five. My main object was to produce a variety that would yield more forage.

Seeds were sown thinly in boxes in the greenhouse, or in plots out-of-doors. Selection was made when the plants were about half an inch high, and before they had put forth their second leaves. At this stage a fairly correct judgment can be formed as to which plants will be rapid growers.

In general, the plant that will ultimately tower above its fellows is found to show superiority in its earliest stages.

By selecting the plants that seem to give most promise, and planting these in rows where the soil is practically the same throughout, it is not difficult to discover the most rapid growers and to weed out the others.

The brome grasses are much more variable than is commonly supposed even by those who are familiar with them. In fact, even within the same species, it is difficult to find two plants that are precisely alike. Some have broad leaves, and some narrow, and the leaves may be variously curled or twisted, as well as variant in color, some being much darker than others.

Some specimens go to seed without producing much foliage; others grow abundant foliage but are tardy of seed production.

The plants that show this propensity to produce foliage rather than seed are, other things being equal, the ones to select, except from the viewpoint of the seedsman, who does not appreciate this kind of grass. I have aimed to get a variety with broad, rich, dark green leaves, and found it comparatively easy to develop such a variety. Notwithstanding the great variation shown by the individual bromes, I found that varieties once specialized tend to come somewhat true to type in the succeeding generations.

Therefore it is a very easy matter to improve the different species of bromes.

By far my most interesting experiment with plants of this genus was made about twenty years ago with a plant, seemingly of the species known as *Bromus mollis,* that was found on the edge of the Santa Rosa Creek, about one mile east of Santa Rosa.

This wild grass bore a long head of rather plump seeds that were without awns, and that suggested to my mind the possibility of the development of a commercial grain. The seeds were planted and carefully cultivated, and the best seedlings were selected for propagation, with the result that in the course of a few years a variety was secured in which the size of the seed head was markedly increased, and in which the individual grains are very much plumper than the original one.

The grain seemed so promising that I tested it by grinding it. It was found to produce an excellent flour with a slight yellow tinge.

When prepared and baked in the ordinary way, it made a very good bread.

I was quite sure that a grain of good commercial value could be produced by further selective breeding from the seed of this brome. But I had only a small quantity of seed, and as other matters took my attention I neglected to plant it for two or three seasons; and when it finally was planted it failed to germinate. So the experiment came to an end in unsatisfactory fashion, yet not without offering interesting suggestions as to the possibilities of development of this and other plants of the tribe.

Unfortunately I was not quite sure as to the exact species of brome that furnished the material for this experiment. Moreover, I have not found another plant that showed the same exceptional qualities of seed with which a new line of investigation might be begun. The one mentioned was discovered only after careful inspection of more than twenty-five thousand samples.

But the finding of one sufficiently proves that there must be others to be found if we search widely enough, so I record the experience as a stimulus to further search and investigation with a tribe of grasses represented by numerous other species that are familiar enough in fields and waste places, but which at present are regarded as weeds rather than as friends of the agriculturist.

Some Cultivated Grasses

Some of the most striking results I have ever seen in the way of development of grasses were obtained with the perennial known as the Sweet Vernal Grass (*Anthoxanthum odoratum*).

This grass is exceedingly variable. A few years ago I raised about fifty thousand plants in boxes. From the seedlings the largest and the smallest were selected; the broad-leaved and the narrow; the dark green and the light green; and those showing any other striking peculiarity.

By planting the individuals that presented these diversified traits in plots by themselves, and carefully selecting their seed, races of perennial sweet vernal grass were obtained presenting the widest range of characteristics.

Thus varieties were produced that would bear almost no seed, and others that bore seed abundantly, some which increased from the roots with great rapidity, and others that increased very slowly.

From among the thousands of plants that were raised and scrutinized, I found two or three that would grow more than one hundred times as fast as the smaller ones. Not only was this startling increase in vigor of growth shown at the outset, but it was continued at the same rate season after season, where the plants were raised by division.

The differences in the growth of the various plants could be detected almost from the moment when their tips appeared above the soil.

But, of course, the selection involved very close scrutiny, and I sometimes spent hours at a time over a box containing perhaps ten thousand to twenty-five thousand plants, selecting two or three that outgrew all others. Here, as with the other grasses, rapid growers in the boxes were almost invariably rapid growers throughout. The seed of the strongest growers was preserved, and the experiment was carried forward with the expectation of developing races of perennial sweet vernal grasses that would not only show improved quality of foliage, but an enormously enhanced capacity for growth.

The practical value of such an experiment as this, from the standpoint of the agriculturist, will be obvious.

That such variations may occur among plants from the same lot of seed gives a clew to the observed differences of neighboring forage fields.

It is clear that the diversities that are usually ascribed to differences of soil may be due in part to different strains of seed. The value of developing a forage grass to its fullest possibilities of productivity is too patent to require comment.

That one plant could be made to grow, and to maintain throughout life a rate of growth one hundred times in excess of other individuals of the same species, is a fact that should be stimulative to any experimenter who thinks of working with the grasses, and that is certainly of significance to the cultivator of forage plants.

I have experimented extensively also, and with interesting if less picturesque results, with the millets, the rye grasses, and orchard grass, as well as with numberless more or less conspicuous varieties.

My work with orchard grass (*Dactylis glomerata*), which was only neglected in the past few years, included an interesting experiment growing out of the discovery several years ago of a seedling that produced leaves much longer than the ordinary, as well as a large, strong stalk, and a large cluster of blossoms different in form from those of the ordinary orchard grass.

The plant was so individual that it could be distinguished at a considerable distance by its greater size and anomalous appearance.

The seeds of this plant were found to follow the variant type of their parent somewhat closely.

The type has not been entirely fixed, but is worthy of further attention. In a few more seasons, according to present indications, it will be so fixed as to produce regularly from seed a type of orchard grass that would nearly double the growth of the ordinary variety.

Another variable grass that I have cultivated extensively in recent years, for observational purposes rather than commercial varieties, and from which new varieties are being developed, is the species known as *Agrostis Fontanesi,* recently introduced from Algeria. From the same plant have been produced seedlings with broad spreading panicles, others with compact spikes, and yet others with beautiful spreading spikes. On sowing seed from different panicles it was found that the tendency to compactness or looseness of head was transmitted or accentuated, so that widely differing varieties were developed in the second generation from seed of a single plant.

Some similar results with Bermuda grass (*Cynodon dactylon*) were obtained. With this I have experimented from time to time during the past twenty years, more particularly in the effort to produce a lawn grass which would fulfill the function in arid regions that the blue grass fulfills in moist climates.

I have found that this grass varies even more than most others do from seed, and by selection was able to produce dwarf varieties, or, on the other hand, the tallest and largest-growing ones; also varieties with broad leaves and others with narrow leaves.

There were plants that came up thickly and made a compact sod, not having the wild running habit of the original variety. And others that sent out runners and spread so rapidly that in a single season one plant would cover the ground for ten feet in all directions.

These extraordinary diversities were shown among plants selected from the same lot of seeds. In all there were at least twenty quite distinct varieties developed, each marked by one or more obvious and striking peculiarity.

But as Bermuda grass is commonly regarded as a weed, none of these were introduced.

Ornamental and Useful Grasses

At various times I have taken great interest in the ornamental grass commonly known as pampas grass, the plumes of which were at one time in great demand.

The form of pampas grass that is most grown in California is that known technically as *Cortaderia argentea.* The plumelike panicles of this grass are familiar ornaments everywhere, and were, in the time of their greatest popularity, articles of some commercial importance.

The plumes to be preserved in the best way should not be allowed to come out of the sheath before drying. The long stems, with several leaves attached, are cut just as the tip of the plume begins to show. The leaves are stripped off, and the stalk is placed in the bright sunshine, preferably standing, but more commonly spread on boards or on the ground. Prepared in this way, the panicles do not shake to pieces. They assume the aspect of silky plumes, which are given a peculiar fluffiness and brought to perfection by being placed in a hot oven for a few moments.

I have raised perhaps a hundred thousand seedlings of various pampas grasses, and have crossed them extensively.

There is no difficulty in effecting cross-fertilization, provided, of course, the two species bloom at the same time. Pollen from the ripe male plant is simply dusted over the pistillate flower. The female plant is the one that is useful for ornament, the male plant having a smaller and coarser plume, which is never silky or fluffy, and which readily falls to pieces under any treatment.

There are pampas grasses, however, that have both staminate and pistillate flowers in the same blossom, and, of course, these cannot be cross-fertilized with such facility.

My most interesting experiments have had to do with the crossing of a pink variety of pampas grass that bears both staminate and pistillate flowers, with some of our finest large white varieties. These plants crossed readily and many thousand seedlings were raised. A large proportion of the seedlings were plants bearing both stamens and pistils like the pink parent. Very few were female plants, and therefore bearers of good plumes.

Even when the plumes were produced, they were usually not as large as those of the white parent, and many of them were smaller even than the small plume of the pink parent. This is easily accounted for by the fact that the great white plume had been produced through artificial selection, and therefore its characters were not as well fixed as in the wild type.

An interesting feature of this experiment was that the pink color seemed to appear oftenest on the staminate plants and not on those that bore both stamens and pistils.

This gives a suggestion of the element of sex selection in heredity, which is seldom observed in plants, although common enough among animals. A further evidence of this was seen in the fact that I was never able to fix the color so thoroughly on the female plants as on the male.

The pampas grass is multiplied by division, so that there is no difficulty about the multiplication of a new variety. The new varieties do not usually come true from seed. But this is of no importance, inasmuch as a single plant may be so multiplied by division as to produce probably fifty thousand marketable plants, on good soil, in the course of two or three years.

Some Miscellaneous Improvements

From among a great variety of experiments looking to the improvement of farm and forage crops, I will select only three or four additional ones as offering further suggestions.

An interesting anomaly with which I have experimented is a hybrid form of the wild oat. A field of the second generation of these hybrid oats furnishes one of the most interesting studies of variation that has come under my observation. Inspecting a field of these oats, sown quite thinly, one finds on the same day some that are thoroughly ripe, while others are not yet in bloom. There is corresponding diversity as to the appearance of the plants, some having broad leaves and some narrow ones.

Some of the plants are very tall, and others short and stocky. The panicles are of all forms and sizes. In a word, the hybrids vary in almost every way in which they could vary, and still be recognized as oats.

It is obvious that such a variant type of oats gives opportunity for selection and development of new varieties.

The tendency to vary as to time of ripening has peculiar interest, as suggesting the possibility of adapting oats—and doubtless also the other cereals—to different climates, or even of the production of different varieties in the same locality, which, by ripening at different seasons, would enable the farmer to avoid the excessive rush of work that attends the harvest season.

Several years ago I worked quite extensively on buckwheat. This work consisted largely of selecting the larger, plumper, and lighter-colored kernels. The work was carried on with both the common buckwheat and the Japanese species. A certain amount of crossing was done, but in general the plants were found to be so variable that nothing more was necessary than to select among the different forms that appeared spontaneously.

Considerable though relatively slow progress was made in the production of a better quality of grain. The experiments were discontinued before I began the extensive hybridization of the two species that had been contemplated. They could, of course, be crossed to advantage.

Among textile plants, and plants of use in the textile industries, my most interesting recent experiments have had to do with the wild teazel, with the Chilean hemp, New Zealand flax, and many others that give promise of the production of a valuable fiber.

The teazel, as is well known, has been an important plant, inasmuch as its long-hooked burs are used for producing the nap on cloth, more especially the woolens, and no mechanical device has ever been invented as a thoroughly satisfactory substitute. There are several distinct varieties of the plant and one of them is a weed that grows along neglected roadsides in California. Among any lot of wild teazels one may find a number of types, and it is not unusually difficult to fix these types by selective breeding.

If it were necessary or desirable for any particular use to make the hooks several times the usual length, or the burs themselves several times as large, this could easily be accomplished.

My work had to do with some of the peculiar forms rather by way of experiment than with any practical idea. The forms worked with were those with vertical rows of hooks, instead of the spiral ones, and with varieties having extra large hooks at the base and double heads. The experiments were carried forward for several years for my own information and education and demonstrated that different kinds of teazel burs could be developed and fixed if desired.

Possibly some modified form of teazel may be of use in a future industry. Hitherto it has not been known that modified forms were available.

My experiments with hemp were conducted largely with an improved Chilean variety, but included also the use of seed from Japan, India, Russia and France, as well as from various parts of the United States. The experiments have grown out of a suggestion that I made a number of years ago to a large Boston paper manufacturer, to the effect that it seemed possible that the fiber of the hemp might be used as a substitute for wood pulp in the manufacture of paper.

The experimental work is only at its beginnings, but it seems to be of considerable promise, especially as to improved size of plant, as a crossbred variety has been secured which outgrows all other hemps. The hemp, as is well known, is a diœcious plant, and it may be well to mention the simple but uncommon method of making crosses. All the varieties are first planted separately; and only a few of the largest and tallest male and female plants of each variety are left to bloom. When the heads blossom, the tallest and best of each variety obtained from different sources are crossed with pollen of the tallest male plants.

After two seasons of this selection and crossing of different strains from different countries, the varieties were combined by crossing, as before, by selecting the largest and tallest plants, out of which a new race was produced of giant hemp.

It was found that a hemp received from China and one from Chile were at first the two tallest and most rapid growers, but they were very shy seed producers in this climate, especially the Chinese one. The variety which I produced from Russia was the most slender, and also the most dwarfed, so this had little to do with the giant hemp which was produced.

Paper made from the fiber of the hemp is found to be of good quality, and although not generally used heretofore must certainly be more prized as other paper pulps become scarce.

I mention this line of investigation here merely to suggest the wide range of opportunities that will become apparent for the plant developer when he has learned to cooperate with workers in the various industries.

Hitherto we have been prone to take it for granted that all the valuable textile plants have been investigated and perfected. The newer studies suggest that there is still boundless opportunity for progress, not only through the improvement of the plants that have been utilized, but also through the introduction of species that have been ignored or neglected.

WHAT TO WORK FOR IN FLOWERS

AND HOW TO PROCEED

ONE of the plant developments that usually interests the visitor as much as almost any other has to do not with the flower or fruit of a plant but with the leaf.

The plant in question is a species of "wild geranium" known as *Heuchera micrantha,* a native of the western coast, and the anomaly of leaf that attracts attention is the curiously crested, crinkled, and corrugated condition that makes the foliage of this plant quite unlike that of any other member of the tribe before seen. Indeed the new variety is so changed from its ancestral type that it is considered entitled to recognition with the varietal name *cristata* added to its technical title. Were it found growing in the woods instead of in a garden, it would per haps be pronounced a new species altogether.

The story of this anomalous geranium will serve as well as another to introduce our studie of the development of new varieties of flowers, even though the particular development under consideration has to do with the leaf of the plant, and not with its blossoms. The principle of its development is the same in its application to each part of the plant, and we shall see plenty of illustrations of work with the flowers themselves before we are through.

The wild geranium, of which the plant with the strange leaf is a modified representative, is a plant that normally has leaves some of which are rather decorative because of their slightly scalloped margins, but which in general are quite plain. Some of the leaves are flecked with brownish spots, but the surface is quite smooth, as much resembling an apple or geranium leaf as any other. Even botanists have never taken special notice of any variation in the form of the leaf.

There is, however, a marked tendency to variation in different specimens, especially in the brown spots on the leaves, and the crimson shadings in the fall.

A New Leaf By Selection

Several years ago, in examining some of these plants growing wild on a dry rocky ledge near Mt. St. Helens, I observed one that had leaves slightly crinkled at the edges. This slight almost insignificant variation suggested a possibility that further variation in the same direction might take place if the plants were educated in the right way. So I transferred the plant with crinkled leaves to my home grounds, and in due time gathered its exceedingly diminutive black seeds.

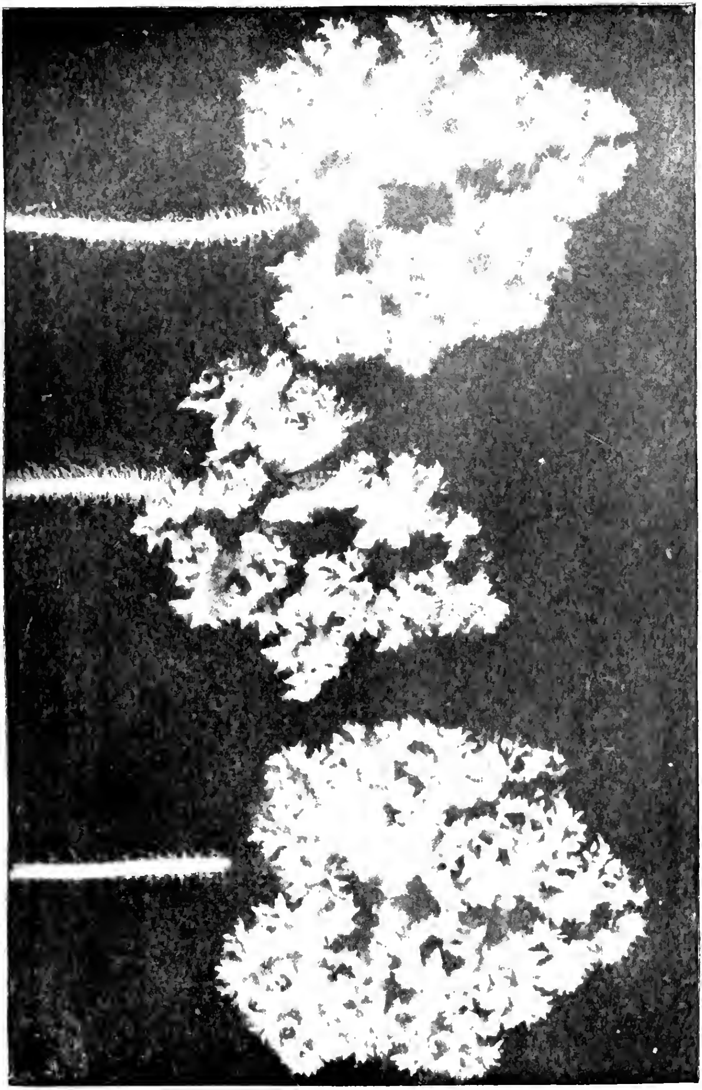
When the little plants that grew from these seeds the next season were carefully examined, I observed that some of them had leaves slightly more crenated or crinkled than the others. So even before the plants made much growth I was able to weed out half of them, as showing no evidence of progress in the desired direction.

When the plants were still larger, but before any flowers appeared, about half of the remainder were pulled up; and later in the season still others were discarded that had shown the crinkled condition at an earlier period but did tend to carry it well as they advanced in age.

Of the many thousands with which I had started in the spring, only a handful remained toward seed time. And at last a single one among these was chosen as presenting leaves that from the point of view of the experiment were best.

VARIATION IN COLOR AS WELL AS IN FORM

These are different examples of our curiously crested "wild geranium"—a plant that has been so modified as to merit botanical classification as a fixed variety. It will be seen that there is marked variation in color as well as form. By selective breeding the color variations are being fixed just as the crested condition of the leaf has been. The modification shown has been effected by selective breeding alone, without hybridization, from the smooth, flat leaf of the common wild Heuchera. (One-half life size.)



This single plant was allowed to mature its seed.

The plants that grew from this seed, representing now the second filial generation from the original wild plant, were treated in precisely the same way. But it should be recorded that there was great improvement in this second generation. Now three-quarters of the plants showed leaves that were markedly crinkled. Each plant produces thousands of seeds, and progress was relatively rapid, as great numbers could be produced from which to select.

By process of elimination, the one best plant was again selected and its seed preserved.

In the next generation practically all of the plants produced the curiously modified form of leaf.

In the fourth generation, as before, very large numbers of plants were raised that there might be wide opportunity for selection. Now all the plants presented the crinkled leaves, but there were of course individual specimens that excelled, and these were chosen to the exclusion of the others.

Their progeny bore uniformly crinkled leaves of the most pronounced type, and they constitute the new species *Heuchera cristata* as it grows to-day.

The remarkable crinkled and convoluted leaves are so interesting that they are sometimes preserved by electroplating, to be used as ornaments. They give the plant a very curious and individual appearance, and present a striking illustration of what may be done, by mere inbreeding and systematic selection, to develop and accentuate a plant characteristic.

No one who casually observed the old parent form of the plant and the new modified form growing side by side would be likely to suspect that the two belong to the same species. Yet an examination of the flowers would show that these are identical, for in making the successive selections I paid attention to the leaf exclusively, and did not seek in any way to modify other portions of the plant's structure.

To the person who has not had experience in plant development, probably the most remarkable feature of the entire matter is the comparatively short time required, and the few generations involved, in producing what is a remarkable transformation—the most conspicuous transformation in a leaf that has ever been produced. The nearest approach to this structure is seen in the leaf of the Rex Begonia called *Erdody.* It may seem further remarkable that a transformation of such significance could be effected in a few generations by selective breeding without the aid of special experiments in hybridizing.

But this case is presented here at the beginning of our special studies of flower development, largely to emphasize the possibility of modifying even so fixed a structure as the leaf of a plant merely by selection of individual specimens that vary in a given direction for a few generations.

I would emphasize, however, the necessity of operating with a large number of specimens if one is to obtain the best results in the shortest practicable time. The account of the experiment just given makes it clear that by having large numbers to choose from, I was enabled to discard numberless specimens that would have answered the purpose *fairly* well in favor of the single specimen that showed the desired quality modified *preeminently*.

The Question of Hybridizing

This case, as was said, illustrates the possibility of producing striking results in plant modification by mere selection without hybridization. No effort was made to induce the plant to vary more rapidly, first because there seemed no necessity for stimulating it to further variation, and secondly because no plant was at hand which presents such a character as the one I wished to develop.

Yet it should not be overlooked that there was an element of pollenizing involved, even though the pollenizing was not done by the plant experimenter. This is almost axiomatic because of course the plant would have produced no seeds unless its pistils had been pollenized.

All that I had done, to be sure, was to transplant the original geranium to a place where it was isolated from any other plants of its species. But such isolation in itself served to provide that the pistils of the plant should be fertilized with pollen from its own flowers.

In other words, by isolating this *Heuchera* with crinkled leaves it had been determined that the pollen and ovules from the selected plant should combine to produce the seed germs for the next generation. And in so doing I made sure that both hereditary strains—that brought by pollen and that brought by ovule—should have the same hereditary factors, because they were borne on the same plant.

This, then, was a case of inbreeding or "intensification" which has been mentioned previously. It was as far removed as possible from the hybridizing experiments we have witnessed in which species of widely different type, say the straw-berry and the raspberry, were interbred. In such a case as that the pollen and the ovule bring groups of hereditary factors that are widely divergent. And even in the usual cases of cross-fertilization within a species, where pollen of one plant is brought to the pistil of the flower of a neighboring plant, there is a certain opportunity for the mingling of diverse hereditary factors, inasmuch as no two plants are precisely alike.

But in the case of our *Heuchera*, the flowers were self-fertilized, or at most the pollen from one flower was transferred by an insect to the pistil of a neighboring flower on the same stalk, and thus it was arranged that both hereditary strains should be as nearly identical as is possible.

In the essential matter of the form of leaf, the hereditary factors brought by the pollen grains called for a leaf with crinkled edges; and the hereditary factors carried by the ovules had the same specifications. So there was the best possible chance that the offspring would reproduce or accentuate the parent character.

And yet the results show that there must have been a certain amount of diversity among the various pollen grains and ovules even of the single plant, inasmuch as the plants that grew from its seed were diversified in character.

About half of them, it will be recalled, did not present the crinkled leaf to any extent and were at once eliminated.

And the other half exhibited the character in varying degree.

Indeed, no two of them were precisely identical, so we were justified in the conclusion that no two pairs of pollen grains and ovules brought precisely the same combination of hereditary factors together.

When we consider the matter in this light, it will be evident that all pollenizing experiments are in a sense hybridizing experiments in one degree or another, inasmuch as they all of necessity bring together pollen grains and ovules that vary somewhat, even if only in very minor degree, in their hereditary factors.

But it remains true—and indeed is too obviously true to require comment—that the case of the pollen grains united with pistils on flowers of the same plant (the case, that is to say, of the *Heuchera* under consideration) is that in which there is the least possible degree of variation between the two sets of elementary factors that are combined.

Therefore this process of so-called inbreeding introduces the least possible disturbing elements, and gives the largest probability of the reproduction of any given trait of the mother plant—which in this case is the father plant as well.

The practical results have been already illustrated in the production of this new race of *Heuchera* with leaves crinkled and corrugated in unique fashion so that they differ fundamentally from the characteristic leaves of any other species or variety.

The lesson to be drawn, then, from this experiment is that when we wish to modify a plant as to some particular feature of its anatomy, we shall proceed to best advantage if we (1) select an individual that shows the most marked departure from the normal in the desired direction of any that can be found; (2) isolate this plant so that its flowers shall be self-fertilized, or else hand-pollenize them; and then (3) follow out a similar course of selection of the best individual and self-fertilization of its flowers through successive generations until the maximum amount of variation in the desired direction has been produced. It sometimes hastens the process to combine two or more of the best plants by crossing rather than to depend on a single one.

We shall see in other connections, as indeed we have previously seen in our studies of many plants, that it is frequently desirable to stimulate variation by hybridizing plants that are divergent, even plants of different species. But when an individual plant presenting an approach to the desired variation or modification has been found among the hybrid progeny, the successive steps of inbreeding and selection, through which the character is accentuated and fixed, will be carried out precisely as in the case of the little *Heuchera* just cited.

Indeed, had we been able to take up the story of our little *Heuchera* a generation or two earlier, we might have found that such a crossbreeding experiment as has just been suggested had been performed for us by nature. It is highly probable that the original specimen with the tendency to crinkle leaves that was found in the woods was the product of a cross between plants, perhaps of the same species, that were individually somewhat variant from one another. The plant grew on a cliff where very dry, very moist, and very unusual conditions of sun, shade, moisture, and soil prevailed, thus having current in its heredity a tendency to vary more or less, since heredity is only the visible effect of near and far environments.

Whatever the individual peculiarities of the parents of this particular plant, the individual that I found had leaves that were somewhat highly accentuated in a certain direction, being thus proved to be the possessor of a somewhat unusual combination of hereditary factors for leaf formation.

In a word, then, whereas the experiment with the *Heuchera* may be described as consisting exclusively (so far as the plant developer was concerned) of a series of selections, it really involved also the principle of the inducement of variation by unusual environment and the fixing of characters by inbreeding.

And these fundamental principles of plant development must be involved, in one degree or another, in all successful experiments in the development and fixing of new types of plant or leaf, flower or fruit.

Let us now witness the application of the same principles to the flower of the plant with reference to the different characteristics of size and color and odor and modified petal or stamen or pistil that may be involved.

Producing a Desired Fragrance in the Flower

Probably no other characteristic of the flower is more highly prized than its odor.

The sweet pea, the rose, and the carnation owe their popularity as much to their fragrance as to their color and form, yet there are numbers of

PERENNIAL PEAS

The Perennial pea has been greatly improved on my grounds during the past thirty years; flowers made much larger and in various new shades and more flowers to each truss. The plants, also, are earlier and more abundant bloomers. (About one-half size.)

very beautiful and popular flowers that are quite without attractive fragrance. There is no line of experimental work with flowers that should be more attractive to the amateur than the development of fragrant varieties of some of these odorless flowers.

And fortunately it is an undertaking that may be expected to produce very satisfactory results —as immediate, as striking, and as valuable results as from any other plant experiment. In any group of odorless flowers you may have the good fortune to detect, if you search carefully enough, one that differs from its fellows in having at least a suggestion of fragrance. And if you will work in the right way with this individual, you will be able to produce a race of perfumed flowers, thus adding the finishing touch to a blossom which, however attractive otherwise, could not be considered perfect so long as it lacked this finishing quality.

In an earlier volume we have heard the story of the fragrant calla.

The reader will recall that this anomalous variety, known now as the Fragrance, was developed by simple selection, along the lines just illustrated in the case of the *Heuchera,* with the difference merely that the characteristic borne constantly in mind was fragrance of the calla blossom instead of a peculiar conformation of leaf.

By "line-breeding" and careful selection, I was enabled in a few generations to isolate a calla that has delicious fragrance while retaining all the other qualities of the flower unchanged.

The seedlings of this selected calla are not invariably fragrant. By careful inbreeding the fragrant calla could without doubt be made to breed true to the quality of fragrance. In the particular case of the calla, this is of no special importance, as the plant is propagated by division.

But in plants that are propagated solely by seed, the fixing of the quality of fragrance would be essential.

Fortunately it presents no special difficulties once a fragrant variant has been found.

In a later chapter we shall learn of other experiments in producing fragrant flowers, and details will be given of the story of my fragrant verbena which was introduced under the name of Mayflower. The amateur who wishes to experiment along these lines may begin with almost any odorless flower in the garden. It is only necessary to search for delicate traces of fragrance, and to learn to recognize nice shades of distinction among odors. Anyone can readily detect the difference in fragrance in several varieties of the violet, rose, or carnation, for example; and a still more highly cultivated odor sense enables one to notice differences in the fragrance of apple, peach, or almost any other blossoms from different trees or plants.

So it is not necessary to confine one's experiments to flowers that lack fragrance altogether. Interesting results may be obtained by selecting among fragrant flowers those that have the most pleasing perfume, and developing those races that are especially notable for their special fragrance.

The failure to give attention to the matter of fragrance sometimes leads to the cultivation of a special variety of fragrant blossom that has altogether lost its perfume. An illustration of this came to my attention not long ago when visiting the seed farm of the best-known seedsman in America. He called attention to his new varieties of sweet peas with great pride; and when I called his attention to the fact that a number of them were totally lacking in fragrance of any kind, he was not a little surprised.

He was breeding sweet peas for immense size and brilliant colors and had succeeded, through selection, in producing very striking varieties.

But he had taken it for granted that all sweet peas are fragrant, and had before failed to observe that these particular ones had no perfume whatever.

Yet this seedsman is an expert who has been for nearly forty years in the business of growing flowers. Like perhaps most others, he had taken it for granted that all varieties of fragrant flowers are fragrant. Series of experiments in crossbreeding would be necessary to reintroduce the perfume to these varieties that have lost this finishing quality.

This case is mentioned to illustrate the fact that a given quality may be dropped out of a strain of flowers while another quality is being bred in. Also to emphasize the point that it is usually well to consider more than a single quality in any breeding experiment. At least it is desirable to see that the qualities already present are not lost in the process of gaining new ones.

Producing New Colors

I am disposed to think that all shades of all colors that can be produced by blending of the primary colors are within the possible attainment of any flowering plant.

The obvious fact that certain species, and in some cases whole genera, produce only red flowers, others only blue ones or yellow, does not by any means prove that the plants in question have not the capacity to produce flowers of quite different color.

We have seen that the colors of wild flowers have been given them by insects. We have noted that the bright colors—reds, orange, blues—have been assumed by flowers that flourish in the daytime and seek association with the bees; and that the flowers that consort with night-flying insects, such as moths, are almost universally decked in white or pale yellow—hues that make them far more conspicuous in the twilight than the most brilliant scarlet flower would be.

Most wild flowers of a given species are of a single color, or of a definite arrangement or combination of colors. Bees and other insects have learned to distinguish this characteristic color or combination of colors, and to go with certainty from one flower to another of the same species, thus unconsciously serving the flower well by cross-pollenizing its blossoms.

I have often thought how confusing it must be to the bees on coming to our gardens to find flowers that perhaps are familiar as to perfume and form now arrayed in a dress of unfamiliar hues. But bees, like flowers, can adapt themselves to their environment. They soon adapt themselves to the new colors and combinations of colors that man has given the flowers, and they go about their task with undiminished celerity and certainty.

Recognition of the fact that wild flowers have been given their colors by the insects through the slow process of natural selection (in which flowers that lack the color were not visited by the bees and hence produced no offspring; whereas the flowers that did produce the color were fertilized, and perpetuated their kind, and reproduced their qualities in abundant progeny) gives us the clue to the way in which we may go about the development of a new color or color combination in a flower.

Suppose, for example, we desire to change the flower from white to yellow. How shall we go about it?

First of all, we must produce thousands of seedlings from our white flower. Let them blossom, and then search among them with the keenest eye to detect a trace of yellow color—which is found more or less in all white flowers—in the flowers of any single plant.

You are almost certain, if your scrutiny is sufficiently keen, to detect some plant that varies an infinitesimal shade from its fellows, showing at least a trace of yellow; for a really pure white is extremely rare in nature.

Select the seed of this plant; sow it next season; and repeat the process of searching.

You will almost certainly be rewarded, if not in the first season, then in the second or third or fourth, by finding flowers that show very much more marked traces of yellow than the original flower. And even if the variation is not very striking at first, you will probably find that it tends to be accentuated after a few generations, especially in certain individuals. Each year you will discover flowers that are yellower than any of the preceding season; and presently you will have a blossom that is as yellow as you could desire, and a new race of plants that will breed true from seed. Placed side by side with the white flowers that were their ancestors, your new race will present a striking contrast.

The fact that you have thus been instrumental in virtually creating a new type of flower can scarcely fail to give you real satisfaction and pleasure.

The fact that you have a flower such as perhaps no one else in the world possesses, and that this has been produced by intelligent and persistent effort, must be a source of quite justifiable self-gratulation.

A YELLOW TRITOMA OR "RED HOT POKER"

The wonderful new forms and colors which have been produced by crossing and selection here are all that the imagination could suggest. Pure fire reds, lemon yellows, orange, cream, and every possible combination; plants dwarf, tall, medium, some everblooming —new creations from a very ordinary plant.

In subsequent studies we shall see that there are methods of stimulating the production of new colors and color combinations through hybridization. But in this introductory chapter I am dealing chiefly with the simpler cases, and suggesting experiments that the amateur may undertake at the outset.

The more complex cases will command his attention in due course.

Meantime it should be stimulative to reflect that, by mere selection, demanding no knowledge of botany, no expert knowledge of horticulture, but only the possession of reasonably acute vision and the exhibition of patience and persistence, it is possible to develop in the most commonplace flower garden blossoms whose color is at once unique and of enhanced beauty.

Nor need attention be restricted to mere matters of fragrance and color.

I have already suggested that it is usually well to consider more than a single quality. Cases like that of the *Heuchera* leaf, in which for a special purpose a single quality alone is considered, are exceptional. As a rule, you may advantageously bear in mind, at the same time that you are developing a new fragrance, the question also of color of flower and size and form.

At all events, so soon as your experiment has reached the stage at which you have a number of fragrant flowers from which to select, all of which have about the same excellence of perfume, you will, as a matter of course, choose among these the one that combines with fragrance the most desired qualities of color and form and size of blossom.

Doubling the Petals and Increasing the Size

As to the matter of size, it is obvious that not much need be said. A glance shows which plant bears the largest flowers. And it may confidently be expected that the offspring of this plant will tend to produce flowers of exceptional size, and that some among these will exceed the parent plant in this regard.

Precisely the same method of selecting, generation after generation, with size of flower always in view, will lead to the production of a race of plants that tend to produce uniformly, under the right conditions of nourishment and care, flowers of a far larger size than those of the ancestral form.

The matter of producing double flowers from a single variety—that is to say, flowers having two or more rows of petals instead of a single row—may present greater difficulties. Not, indeed, that any new principle is involved, but merely that a longer series of experiments may be required to produce the coveted double flower. The start must be made here just as in the other cases, by searching among the hundreds or thousands of plants for one that bears flowers having even a single extra petal.

Seed of this plant being sown, it is likely that among the offspring there will be some that produce not merely one extra petal, but possibly two or three.

The Three Requisites

Now you are on the road to success. Thenceforward it is only a matter of time, skill, and patience—the three essential requisites of plant development—combined with the dealing with large numbers of individuals.

Exceptionally there may suddenly appear a seedling producing flowers that are fully double. In such a case, if the truth could be known, it would probably appear that some of the ancestors of the seedling had produced—perhaps generations back—a double or partially double flower. Breeding from a double rose or carnation, almost all the seedlings revert to a single or semi-double form.

But in any event, once you have singled out a strain of flower that has the tendency to produce extra petals, you will probably find this tendency accentuated, manifesting what I have elsewhere referred to as the momentum of variation, and giving you results that are more and more encouraging each season.

Asking Too Much

Should you attempt to produce a double flower coincidently with the attempt to improve the fragrance, color, and size of the same flower, you may presently discover that you are asking rather too much.

The flowers that improve in odor and color and size may not be the ones that show the increased tendency to doubling of petals.

In such a case, you may segregate the two groups, and carry forward the two lines of experiment coincidently in neighboring plots; and when you have attained a fair measure of success in giving one race of flowers perfume and color and size, and the other race a double or triple or quadruple row of petals, you may readily make a crossbreeding experiment through which you may combine all the desired qualities in a single hybrid offspring.

Even if the first-generation seedling of such a cross does not give you just the combination you are seeking, the second-generation offspring or a subsequent one are almost sure to reveal some plants that meet your expectations.

So your simple experiments that began by mere selection will probably lead you to experiments in crossbreeding.

The Two Basic Elements

Thus by natural stages you will have learned how to handle the essential tools of the plant developer. You will have learned that the two forces of heredity and environment are everywhere operative, and must everywhere be your sole dependence. But you will have learned also that your wishes become an important part of the environment, when you determine which flowers shall be permitted to reproduce their kind; and that you also take a hand at determining the line of action of hereditary tendencies when you cross-pollinate the flowers, and decide which strains of heredity shall be blended.

Let me in concluding this preliminary chapter name two or three common flowers with which the amateur may advantageously begin his work in selective breeding.

The rose and the carnation naturally suggest themselves, but they have been so much worked on that they do not leave so much opportunity for wide improvement as some less popular flowers, though offering grand opportunities for immediate but less unique results.

The tulip is inviting, but calls for a good deal of patience.

Perhaps the four-o'clock would serve the purpose as well as any other common flower. Also the hyacinth, the *Scilla,* and the gladiolus are peculiarly good flowers on which to work. There are many beautiful varieties of all of these but new sorts could readily be produced. Moreover, they are grown from bulbs, so any new varieties may easily be perpetuated—a consideration that is by no means without significance to the amateur who wishes to obtain striking results with the least expenditure of time.

Details as to numerous other flowers, including both very common ones and those that are less usual, and varying from the simplest to the most complex, will come to our attention as we now take up in succession the records of my own work during the past forty-five years in the development of new races of flowers.

WORKING WITH A UNIVERSAL FLOWER—THE ROSE

How the Burbank and Other Roses Were Produced

THE most popular of any roses I have so far introduced is undoubtedly the one known as the Burbank.

The popularity of this rose is, I trust, well deserved. But I should not be disposed to admit that its merits are greater than those of many of my newer roses which have not yet made their appearance in public. The popularity of the Burbank is partly to be explained by the fact that it has been longer before the public.

There is a time element in the introduction of a new flower, just as in the introduction of a new fruit. In fact, no new plant development could be expected to make its way except very gradually at first, although if valuable it gains momentum rapidly after a time. In this regard, the introduction of a flower is analogous to the development of the flower itself through successive generations of variation.

We have seen that when any given variation is in question, there is a tendency to much more rapid change after the experiment has progressed a certain number of stages.

Similarly a flower or fruit that the public at first accepts rather grudgingly may at last become so popular that it is impossible to produce it rapidly enough to meet the demand.

The Burbank rose, to be sure, did not fail of recognition from the outset. But its gaining of the gold medal as the best bedding rose at the St. Louis International Exposition in 1904 doubtless advertised it most extensively, and led to its rather exceptionally rapid acceptance by the public.

On my own part, I look with particular pride on this rose, not so much because it received the gold medal as because competent judges everywhere have admitted that it deserved the recognition thus given it as the best bedding rose then known.

I have produced many plant developments that are much more spectacular than this new rose, and many that have elements of far greater novelty and interest from the standpoint of both plant developer and the general public. Yet I may be permitted to indulge in a rather exceptional satisfaction over the success of this flower for the reason that the rose is probably the most popular of all cultivated plants, and the one that has received most attention from horticulturists of all classes, professional and amateur alike.

In attempting to introduce a new rose, then, the plant developer is coming in competition with a vast number of workers, and the product with which he operates is to be measured against an almost bewildering number of similar products that have attained a high degree of improvement. So, as I said, the plant developer may sometimes regard with greater satisfaction such an accomplishment as this, than a more spectacular achievement in plant development in a line where there is no competition.

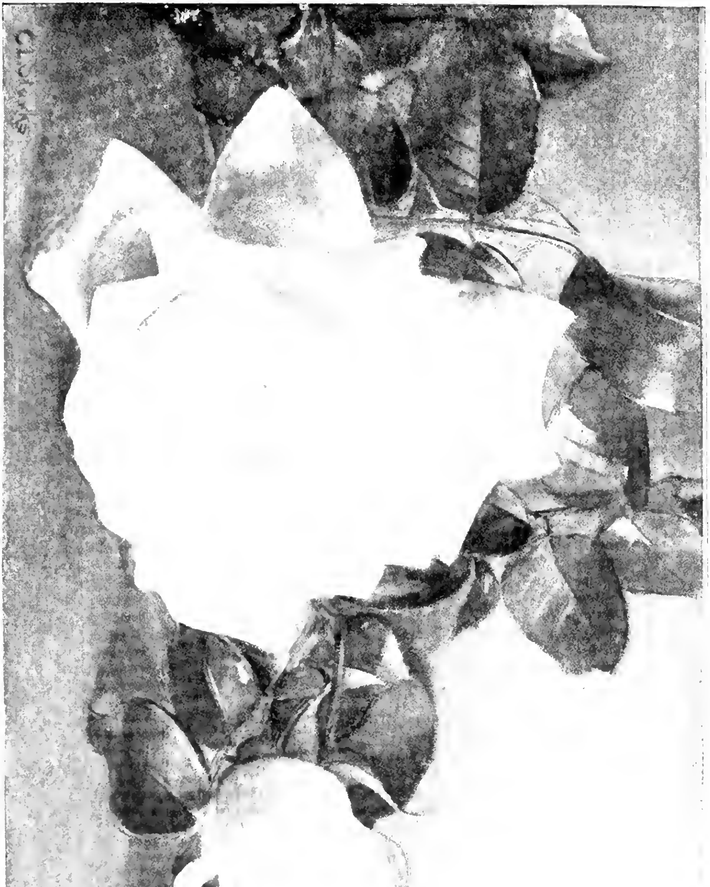
How the Burbank Was Produced

The origin of the Burbank rose suggests in a way the origin of that very different plant development, the Burbank potato.

I was not personally responsible for either name, and the analogy between the manner of production of the rose and the potato was doubtless not at all in the mind of the dealer who christened the new flower. Still, as I have just intimated, there is a certain added propriety in

THE BURBANK ROSE

This picture reproduces a direct-color photograph from an oil painting. It represents the celebrated Burbank rose with the utmost fidelity. This is the rose that secured a gold medal at the St. Louis International Exposition in 1904, *as the best bedding rose. This rose is a truly perpetual variety, blooming constantly wherever climate will permit. The foliage is always and everywhere absolutely mildew, rust and disease proof.*



the use of my name in connection with this particular rose as against a good many other roses that I have developed, because of the fact that the manner of its production suggested that of the production of the first of my important plant developments. In a word, the Burbank rose, like the Burbank potato, owes its origin to the discovery of a seed pod on a plant that rarely produces seed.

The plant in the present instance was a Bourbon rose, of the familiar and typical variety known as Hermosa. This rose very rarely bears seed, even in California, but on one occasion I discovered half a dozen seed pods on a plant that did not differ otherwise in any obvious way from its companion plants.

These seeds were carefully treasured, and from the plants that they grew are descended not only the Burbank rose, but also the Santa Rosa, and a number of others that are less well known.

With the fact that the Burbank rose was a product of seeds thus accidentally garnered, however, the analogy with the Burbank potato ceases.

For, whereas the tuberous vegetable was produced in full perfection on one of the plants grown directly from the seeds found in the potato ball, the Burbank rose was developed only after numerous hybridizing experiments in which new blood was introduced, and new qualities were brought into the combination.

Among other roses, the strains of which were mingled with those of the offspring of the Hermosa to produce the Burbank, was the Bon Silene. And there were at least three or four others that are similarly to be credited, although the exact pedigrees of all of them are not matters of record.

Still the initial impulse to variation which supplied the material for the new hybridizings, and was thus primarily responsible for the outcome, was given by the seeds gathered from the Hermosa. The same tendency to increased vigor and productivity and variation that we saw manifested in the case of the potato, and to which reference has been made also in the case of the sugar cane, and of other plants that are usually propagated by division rather than by cross-fertilization, was doubtless given the seeds of the rose by a chance mingling of just the right kind of pollen—brought by some vagrant bee—with its usually unreceptive ovules.

The lesson that cross-fertilization gives vigor, and provides the materials for variation, which we have seen emphasized so many times, is here given a fresh illustration. It is a lesson that the grower of roses and other long-cultivated flowers may well bear in mind.

When the resources of selection have been practically exhausted, and a particular variety of flower has reached a static period, in which it seems to present no further opportunity for development in a given direction—say as to its odor, or its color, or its size—the plant experimenter should never forget that there still lies open to him the possibility of introducing new elements of variability, and new opportunities for improvement, through hybridization.

This, of course, assumes that the flower has not been so specialized that all its stamens have been transformed into petals, so that it becomes absolutely sterile. Such a transformation has, indeed, been effected with a good many of the cultivated flowers, including some of the roses. And the case of Hermosa, just cited, illustrates the fact that some of our roses are practically sterile. Indeed most of them are so.

But then the flower that has ceased to have productive stamens may sometimes still have a receptive pistil, so that new blood may be introduced from a species that retains normal virility—although in general, such flowers show small capacity even for accepting the pollen.

A NEW YELLOW RAMBLER

The ramblers, of many types, are favorites everywhere. Here is a yellow one that has obvious distinction. As yet it has no name. Profuse and beautiful in bud and bloom.

Characteristics of the New Roses

The new Burbank rose and its sister plant, the Santa Rosa, present further object lessons in the value of cross-fertilization, in that they are not only much more beautiful than the original Hermosa from which they sprang, but that they also have qualities of hardiness and of productivity that are the token of their mixed heritage.

These new roses are, indeed, so hardy that they thrive in the northernmost parts of the United States and in southern Canada. They, are, perhaps, the hardiest of all everblooming roses.

Their vigor and capacity for production of flowers are so great that they bloom incessantly throughout the season. Among all the roses there is none that excels them in the matter of almost perpetual blooming. The number of flowers produced by an individual plant is also quite out of the ordinary.

Meantime the flowers themselves are very superior in color to those of the Hermosa, and the foliage of the plants is glossy and brilliant.

These qualities were of course taken into consideration by the judges who gave the gold medal to the Burbank. But there were others which were given, no doubt, almost equal attention by the experts. One of these is the vigorous habit of growth of the plant, through which it comes about that it may be propagated almost as readily as a weed; will root almost as easily as blue grass, and will bloom when only two or three inches in height, and keep on blooming month after month, and year after year, if the buds are not actually frozen.

Another exceptional quality, which some practical horticulturists might regard as constituting a merit surpassing all the rest, is the power of resistance of the Burbank rose—which the Santa Rosa shares—to those ever-present foes of the rose family, mildew and rust.

The new roses appear to be absolutely immune to the attacks not alone of these, but of other fungoid enemies.

Their healthiness under all climatic conditions is their final and definitive quality.

Making Plants Immune to Disease

This quality of immunity to disease, while primarily due, no doubt, to the enhanced vitality given the plants through hybridization, has been accentuated and developed by persistent selection.

In this regard roses do not differ from practically all other plants with which I operate. I have referred more than once to the method of developing immune races of plants, and emphasize it once more with propriety in the present connection, because, as is well known, the rose is peculiarly susceptible to the attacks of many fungoid and insect enemies.

Indeed, many a rose that would otherwise have value is so susceptible to the attacks of disease that it not only gives no pleasure to its owner, but becomes a source of infection in the garden that makes its presence a menace to other flowers.

To give plants immunity to the chief diseases to which their species is subject is, therefore, one of the prominent aims that I never overlook in the course of experiments, no matter what the particular quality that may be chiefly sought.

Therefore it is made the invariable rule, whatsoever the plant with which I am working, to examine the seedlings attentively from time to time, to note whether any of them give evidence of infection by mildew or any fungous growth.

And any seedling that is seen to be subject to mildew is at once destroyed, regardless of the value of its other qualities.

I should not regard a plant experiment successful that led to the production of the most

ROSES AT SEBASTOPOL

This picture gives a characteristic glimpse, in blossoming time, of some of the rose seedlings. Of the thousands tested, one or two may be saved, but not unless they are better than any rose now known.

beautiful and most fragrant and most prolific of roses, if at the same time the plant that exhibited these qualities was susceptible to mildew. Indeed, thousands of otherwise promising roses have been destroyed for the simple reason that they were subject to mildew.

I have obtained scores of climbing roses that were worthy to compete with the Crimson Rambler or the Philadelphia Rambler and other standard varieties, yet which have not been allowed to live because of their susceptibility to disease.

But the reward of this unflinching application of a principle has resulted in various types of roses that are quite generally mildew-proof.

Among the ramblers just referred to, for example, by sedulous application of the principles of selection, preserving only those plants that showed themselves to have the quality of inherent resistance to the fungus, I have remaining, after thousands of their fellows have fallen by the wayside, a few rambler roses of wholly new types, which are immune to disease. This selection is not as difficult as might be supposed, because a rose that is intensely susceptible is generally attacked during the first one or two years of its existence.

Moreover, these new mildew-proof ramblers manifest, partly perhaps as an evidence of the vitality that makes them immune to disease, a capacity to produce enormous clusters of the most beautiful flowers that approach the keeping qualities of some of the everlastings.

Some of them will last at least a month, on the plant or when cut, showing thus a degree of permanency hitherto quite unheard of among roses.

Origin of the Robust Ramblers

There are a great number of varieties representing different crosses between the well-known Crimson Rambler and such roses as the Empress of India, Cherokee, Agrippina, Baltimore Belle, Banksia, Bon Silene, Papa Gountier, Cloth of Gold, Madame Edouard, Herriot, General Jacqueminot, La France, Lamarque, Maréchal Niel, Cecille Bruner, Mrs. Robert Peary, Paul Neyron, Persian Yellow, Rainbow, Reine, Marie Henriette, Fortune's Yellow, *Wichuriana,* and some hundreds of others.

The cross of Empress of India with Crimson Rambler often have enormous stems, with deep-red hairy branches; while the hybrids of other crosses often have slender, smooth branches.

But the hybrids themselves have been interbred, and other strains that seem to give good promise were brought into their heredity, so that they have traits that do not belong to any of the original parents.

Some of these new ramblers have very large, broad crimson prickles; others have long slender ones set very closely together; still others are quite without prickles, being as smooth as the Banksias.

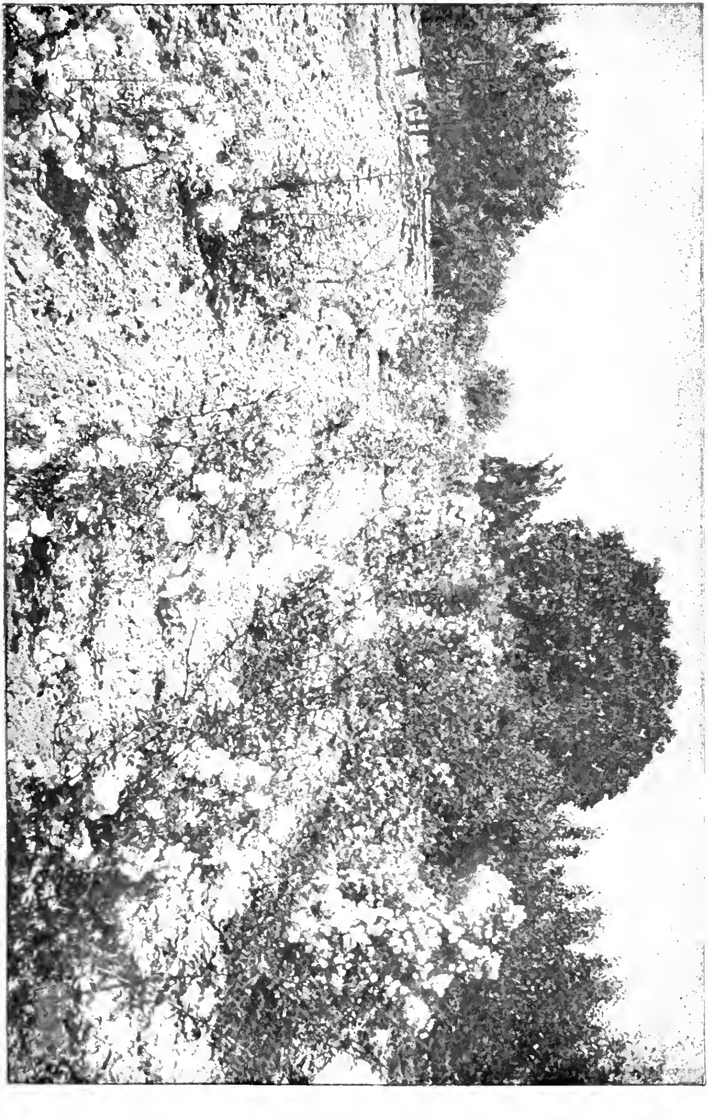
In color the new ramblers vary through crimson, scarlet, and pink to snowy white. Moreover, some of them resemble the Japanese primrose in color, and, when trained on a wall, present such a unique appearance that they would not be recognized as roses when viewed from a little distance. These in particular are especially long keepers.

In explanation of what has just been said as to the uncertainties of the precise lineage of some of my roses, it may be added I have experimented first and last with a very large number of species and varieties of both commonly cultivated and wild ones, and I have not found it expedient or of any special significance to attempt to keep a precise record of the hybridizations after they become very complex.

Yet, for a good many years, to be sure, I kept accurate check on the various crosses.

GLIMPSE IN THE PROVING GROUND

Another corner of the Sebastopol rose colony. The flowers here are not massed for display, but are disposed in rows for convenience of observation. As seen here, they represent transition stages; and a glance shows that some of them may be worth saving.



The names of the parents used in an original hybridizing experiment were always recorded.

Later, as the cross became more complex, large numbers of species being utilized, short cuts were made by using numbers and letters on my labels, the key to these being recorded in the plan books.

This worked very well for a few years more. But there came a time when an experiment with a single strain of roses had been carried through so many generations that the traits of ten species or more would be combined in an individual.

At this stage the numbers and letters were abandoned, and I have contented myself with a general knowledge of the principal ancestors in the pedigree of any new variety, distinguishing the new variety itself by a temporary name for purposes of further record.

Thus I have, for example, grown upward of two hundred thousand seedlings from the Crimson Rambler pollinated with all the ordinary roses that are under cultivation in California. Then it is possible to cross the hybrids with numerous other hybridized roses, some of which would not cross, or cross very unwillingly, with the Crimson Rambler itself.

The parents for the new crosses being themselves hybrids of complicated ancestry, it is obvious that the pedigrees in a few generations become so complicated that if one were to attempt to trace them there would be little time left for any other experiments, and so I have contented myself with watching for results among the hybrid progeny of these roses of multiple ancestry.

There are a few of the new developments that carry strains of almost every rose generally known and cultivated up to within ten years ago, and several species not under cultivation.

Some Ancestors of the New Roses

It would be superfluous to name all the species that I have had under cultivation and have tested as to their possible value as hybridizing agents.

Even were I disposed to make such a record, it would necessarily lack finality. For there are perhaps few plants regarding which botanists are more at variance, when it comes to the matter of classifying and differentiating the species.

It is recorded, for example, that some classifiers estimate the total number of species of roses at about thirty; whereas, on the other hand, a French botanist of some authority has described no fewer than 4,266 species from Europe and western Asia alone. Meantime, botanists in general are disposed to recognize something over 100 species, not always being able to agree as to which forms are entitled to rank only as varieties.

If there is such uncertainty among the professional classifiers, it goes without saying that the vagueness of characterization of different alleged species and varieties is far greater among practical horticulturists. There are, to be sure, a good many pretty clearly fixed types that are everywhere recognized as having individuality. But each of these is represented by many varieties, and these varieties tend more or less to run into one another. This can hardly be otherwise, considering the extent to which hybridization takes place.

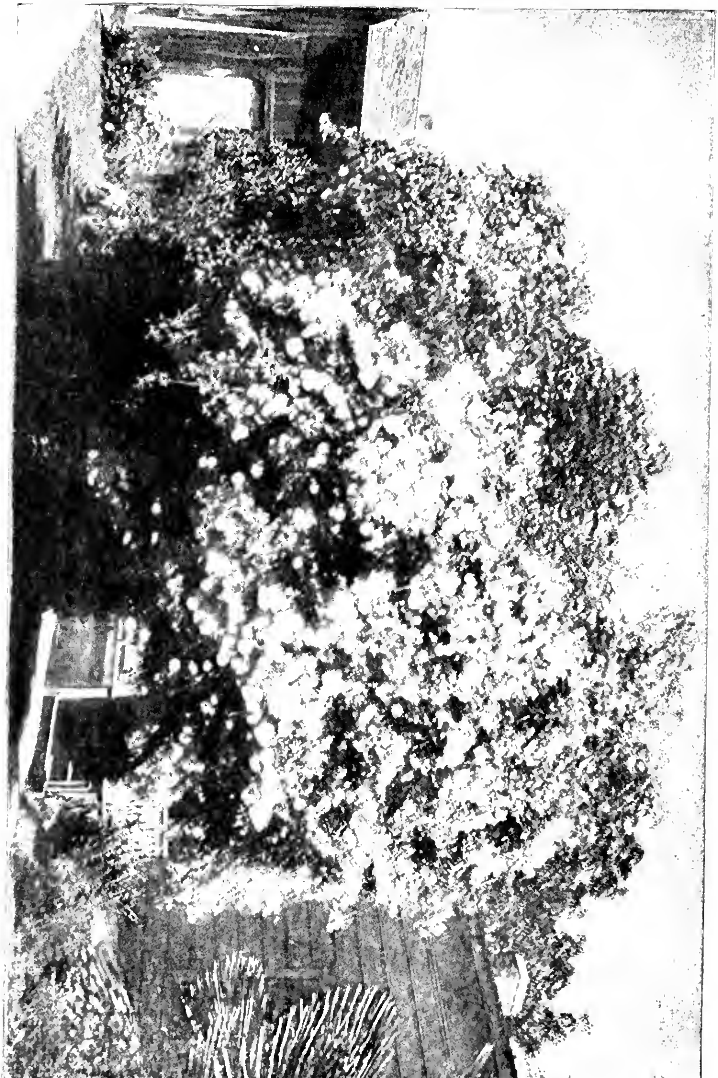
Therefore, it would be impossible to make clear record of all the species of roses that have been utilized in these experiments, even were it desirable to do so.

But it may be worth while to name a few of the more conspicuous ones that have been of exceptional service, and the hereditary factors of which have been blended and intermingled to produce the new types of roses.

The white and buff Banksias, which are abundantly grown in California for ornamenting houses, trees, and arbors, have proved of service because they are very rapid growers, and are practically without thorns.

A MAMMOTH BOUQUET

A number of seedling rose bushes have grown together, to form a mammoth cluster. Of all the interesting and spectacular flower exhibits, few are more popular than the various masses of roses of many new varieties. These are selected seedlings for further trial.



The *Rosa gymnocarpa,* which is indigenous to British America and California, is a pretty and graceful rose, producing fine single flowers that grow in large clusters, and having the element of hardiness that characterizes the wild plant.

The Chinese rose, in numerous varieties (*Rosa chinensis*), and the Japanese rose (*Rosa rugosa*) have made their influence felt in many hybrids. So also has the *Wichuriana.* The seed pods of the Japanese species are unusually large and handsome. The hybridization of the Japanese rose with the Bon Silene and with other strains, including the Hermosa, produced a number of admirable roses that I have introduced, including the Coquito and Peach Blow.

The General Jacqueminot, one of the best known of the hardy perpetual bloomers, is itself a hybrid—as indeed are all other cultivated roses, no doubt, could we know their precise pedigree.

It is a hardy and prolific plant, and its qualities are curiously prepotent when it is crossed with other varieties. This applies not merely to the form and color of the flower itself but to the entire structure of the plant. Its chief characteristics seem to have peculiar prepotency or dominance. But of course the latent characteristics of the variety with which the Jacqueminot is crossed may reappear in later generations.

In striking contrast with the virility of the Jacqueminot is the approximate sterility of the hardy old-fashioned Persian rose.

This has blossoms of the handsomest yellow color, and on this account was regarded as a desirable parent for hybridizing experiments, notwithstanding that it blooms for only a short season in the early summer. But not only does the Persian rose itself fail to produce seed, but its pollen seems to be sterile when applied to the pistils of other flowers or fails to reveal its character in the seedlings. For many years I attempted to hybridize the Persian rose with the Tea rose, Perpetuals, Banksias, Multifloras, Bourbons, Wichurianas, and many others, but in no case did I succeed in making a useful combination. Nor was the experiment more successful when an attempt at a reciprocal cross was made. The pistils of the Persian rose failed to respond to the stimulus of pollen from whatever source. So, of course, there was no strain of the Persian rose in any of my hybrids. This variety has seemingly reached a stage where it can apparently be perpetuated only by division.

Enough has been said to show that the rose is a very tractable flower. Indeed, the very fact of the number of its species and varieties sufficiently attests its variability and receptivity.

Moreover, the rose is entitled to be considered preeminently the universal flower. It doubtless excels all others in popularity and it differs from most others in that it is prized equally in its different varieties for its form, its color, and its fragrance.

As to all of these, to be sure, approximate perfection appears to have been attained with a good many varieties of roses. Yet the fact that new varieties are from time to time put forward shows that there is always opportunity for improvement. I have emphasized certain directions in which the improvement of the many varieties is possible—notably in the matter of hardiness and resistance to disease.

The Opportunity for New Roses

But, in fact, the list of qualities that are taken into consideration by the connoisseur as well as the commercial grower of roses is so extensive that there is opportunity for development through selective breeding of almost any existing variety as to one or another trait that it lacks. Abundance of bloom, lasting qualities of the flower, beautiful buds, long stems, handsome foliage—these are qualities in addition to the fundamental ones of hardiness and resistance to disease that must be taken into account in estimating the

THE CORONA ROSE

This is a crimson rambler seedling, of mixed heritage, that has such altogether notable qualities as to justify its introduction. It is named the Corona. The flowers resemble enormous primroses, and, what is very unusual, have thick waxy petals, which keep fresh two weeks, while most roses fade in as many days.

value of a rose. Then there is one other characteristic of the rose which has hitherto scarcely been considered by anyone, yet which seemingly lies within the possibility of development. This is the matter of increasing the amount of pulp that incases the seed pod of the rose. So much attention has been given to the flower that no one has given heed to the fruit. But it is familiarly known that the rose belongs to the same natural order with the apple, the pear, and our other chief fruit growers of the orchard. So it is a reasonable assumption that this plant could be educated, were sufficient attention paid to the matter, to produce an edible fruit.

Even as the case stands, the fruit of some of the wild roses is sometimes eaten by children, though its proportion of pulp to seed is so small as to be almost negligible. And what has been accomplished with other members of the tribe makes it seem probable that the pulp could be developed and the seed correspondingly decreased until the fruit became quite transformed.

I have said that the rose is the universal flower. Doubtless it already takes first rank among the flowers that man has brought under cultivation. But if it could be made to supplement its wonderful blossom with a really valuable edible fruit, the preeminence of the rose among all the plants that man has placed under cultivation would be still more firmly established.

There is a time element in the introduction of a new flower or fruit. In fact, no new plant development could be expected to make its way except very gradually at first; although if valuable it gains momentum with great rapidity after a time.

IMPROVING THE AMARYLLIS

Wonderful New Blossoms Nearly a Foot in Width

I TAKE it that a flower ten to twelve inches across occupies about the relative position among flowers that a man ten to twelve feet high would occupy among men.

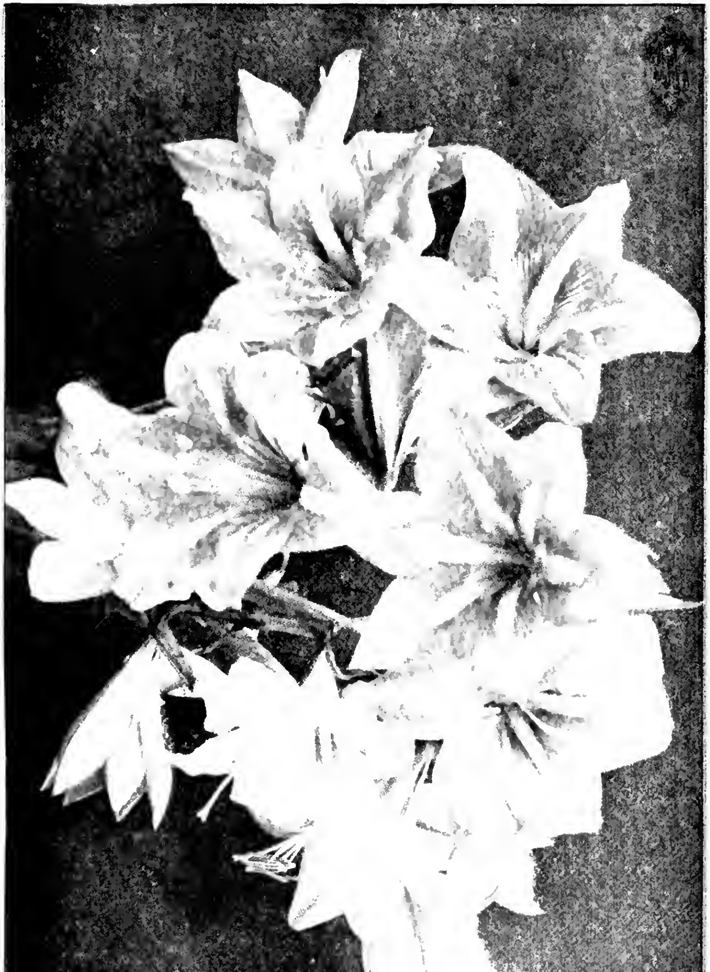
Doubtless you have never seen a ten-foot giant, for I believe there is no record of any human being of that size. And presume that you have never seen a ten-inch flower, unless one of my giant amaryllis blossoms has come to your attention.

At all events, it is rare indeed that any flower here in the temperate zone attains even approximately such a size. The blossoms of some of my new artichokes spread out to the same dimensions as *Lilium auratum,* and exceptionally there may be an individual blossom of some other species that has a spread that approaches the same mark.

In general, however, as everyone knows, flowers are accounted large if they exceed six inches

GIANT AMARYLLIS

The Hœmanthus, or blood lily, is a South African bulbous plant, of flowers ever known. The size was so accentuated that blossoms of the most dazzling colors, eight to ten inches across, were quite common. The range of colors, too, was wholly unprecedented. These wonderful varieties have now been distributed to all parts of the earth.



in diameter, somewhat as a man is accounted large if he exceeds six feet in height.

But several of my new giant amaryllis, with their ten-inch spread of petals, are very anomalous and extraordinary flowers. They occupy among flowers a position not very different from that which would be occupied among men by a ten-foot giant.

If no ten-foot giant has ever appeared, it is probably not so much because the human race does not have potentialities of producing such a specimen, but that experiments in selective breeding of men for the quality of size, comparable to the hybridizations that produced the giant amaryllis, have never been carried out during a series of generations.

Breeding Giants

Everyone has heard of the attempt that was once made by a Prussian king to develop a race of giants by selective breeding.

As the story goes, the king marshaled all the tall men he could find into a special regiment, and sent inspectors over his kingdom in search of tall women as wives for his tall soldiers. He intended thus to produce a royal bodyguard of giants that should be the astonishment of the world.

And no one who has followed out a series of experiments in selective breeding of plants, and who realizes the essential identity of the principles of heredity, applied to man and plants alike, will doubt that the would-be developer of a race of giants was on the right track.

He was starting out in just the way that I started when aiming to produce a race of amaryllis plants that would grow gigantic flowers.

But even had the royal experiment in man breeding been carried forward by the successors of the originator of the idea, it would have been a long time before a giant appeared among the royal guards that overtopped his fellows in such proportion as the giant amaryllis outspreads its companions.

For there is a time element in these breeding experiments that cannot be ignored; and the units of measurement are not years but generations.

In the case of the amaryllis a generation varies somewhat with different species and varieties, but frequently is not more than two years. In other words, some varieties of amaryllis will produce seed in their second year, when grown from seed. And at most three or four years generally suffice to bridge the gap between successive generations.

But a human generation spans a gap of something like a quarter of a century. As a rule the most vigorous and healthy offspring are not born until their parents are at least twenty-five years old. So in making an analogy between the breeding of a giant amaryllis and the breeding of a giant man, it is necessary to bear in mind that ten generations of the amaryllis are compassed in the span of a single human generation.

In other words, the plant developer may logically hope to produce with his amaryllis, in a period of twenty-five years, a development comparable to that which the royal breeder of giants could hope to have duplicated only in the reign of some successor, perhaps of another dynasty, 250 years later.

It has taken at least ten generations of hybridizing and selection to produce my giant amaryllis.

So we may assume that if the project of the Prussian king, which was inaugurated about the middle of the eighteenth century, had been systematically followed up by his successors, there might be a possibility that a ten-foot giant would have appeared among the descendants of the giant guardsmen about the year 2000 A. D.

We may add, however, that it would probably have been necessary to extend the search for

HÆMANTHUS BLOSSOMS

The Hæmanthus, or blood lily, is a South African bulbous plant, of which there are many species, belonging to the same family with the amaryllis. It will be seen that the flowers of this particular species are very attractive in themselves; but their chief value is their possible availability for hybridizing experiments.

giants, to breed into the strain of royal guardsmen, far beyond the bounds of Prussia.

Reasoning still from plant analogies, we may assume that the full measure of possible development in the direction of the ten-foot giant would have been attained only when mingled with the European races.

And in making this illustration I am only seeking another way of emphasizing the truth which we have seen illustrated in many fields, that the widest possible range of variation, and therefore the greatest possible opportunity for development along any given line, can be stimulated only by the hybridization of species or varieties that are divergent almost to the limits of affinity—using the word affinity in the sense defined in our earlier studies of cross-fertilization.

It was thus that my gigantic walnut trees were produced, as the reader will recall.

It was thus that the fruit of the little beach plum was magnified from the size of a berry to that of a nectarine.

It was thus that the giant among small fruits, the Phenomenal berry, was brought into being.

And such also was the origin of the giant spineless cactus plants, and of numerous other plant developments in their way quite as remarkable, even if not always so spectacular.

Flowers versus Men

With the breeding of a giant race of men, we are of course as little concerned as the successors of the Prussian king who inaugurated the short-lived experiment.

There is no real demand for a race of human giants. They would not fit into the scheme of things. Houses and carriages and furniture are not built for them. At best they would be but curiosities, and the world produces quite enough human curiosities by accidental breeding without starting out systematically to secure them.

But it is quite otherwise with plants. Here the production of unusual variations—that is to say, plants that differ conspicuously from their fellows of the same species—is an object considered quite worth while, because these plant varieties, provided the anomaly they present has to do with some inoffensive quality, give pleasure and profit to plant lovers everywhere, and add to the sum total of human happiness.

Such a product as the giant amaryllis, for example, excites universal admiration.

The mammoth flowers are things of genuine beauty, regardless of size; and if mere size does not in itself accentuate the beauty, it at least does not detract from it, and it brings to the beholder an added sense of wonderment that enhances the satisfaction with which the flower is viewed, and gives a pleasurable stimulus to the imagination.

So it may be assumed that the task of developing this unusual flower was a task quite worth the doing. It called for many years of earnest effort, of patient waiting, and of intelligent selection. But the results fully justify the effort.

The story of the difficulties encountered in the early day of my experiments with the amaryllis in effecting cross-fertilization of the flower has been told in an earlier chapter. The reader will recall that I was first unaware that the pistil of the flower matures at a later date than the stamens; hence that for a time I applied pollen carefully to the pistil of flower after flower before it had attained the receptive stage, and so failed to get any results.

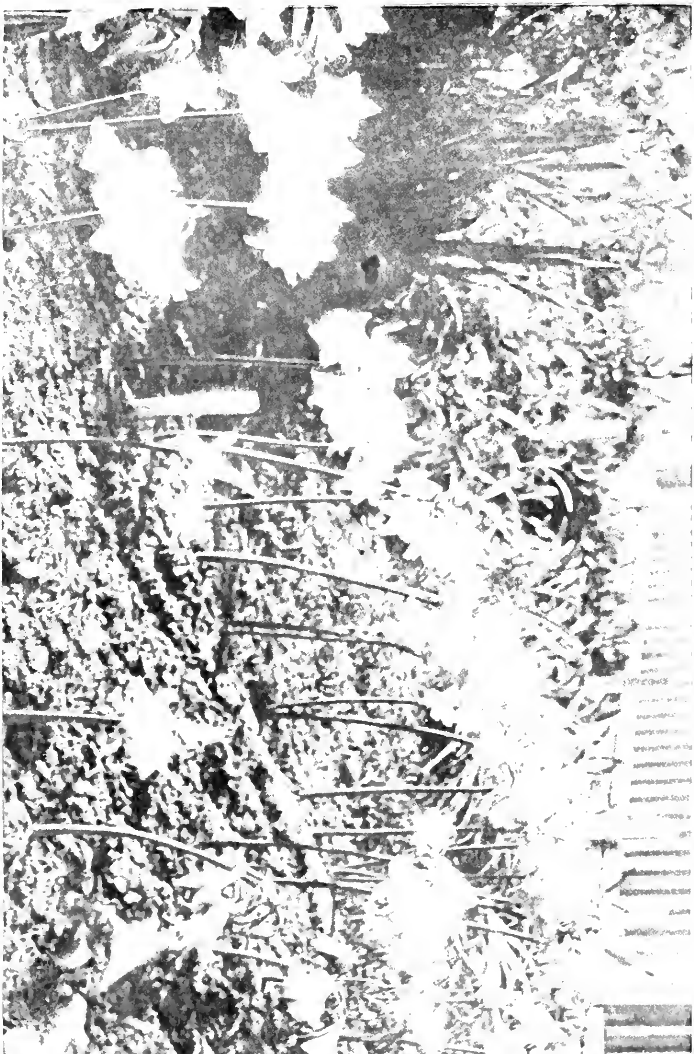
But in due course I learned that the pollen must be taken to the pistil of a flower that has shed its own pollen several days earlier and when I understood this simple feature of the technique of cross-fertilizing the amaryllis, I had no further difficulty as to that part of the experiment.

Materials for the Experiment

The material with which I began my experiments consisted of a few familiar species of the

SEEDLINGS OF THE BELLA-DONNA LILY

This is the Amaryllis belladonna; a true amaryllis, unlike most of the plants that go by that name in the catalogues of the horticulturist. The amaryllis of the gardener is usually a plant of the genus Hippeastrum, but the name amaryllis has been so generally given to the plants of this genus that it would be useless to attempt to change the nomenclature. These are greatly improved selected seedlings awaiting several years' test; most of them are larger and far more brilliantly colored than the original type.



genus *Hippeastrum.* Properly speaking, this genus should not be called amaryllis, as that name belongs to an allied genus with which we shall make acquaintance presently.

But the various species of *Hippeastrum* are known universally as amaryllis to the florist, and it will be convenient here to follow the general custom of applying that name to all the members of allied genera that are grouped together horticulturally and everywhere referred to as if they were of one tribe.

We shall see presently that the members of the different genera, including not only the hippeastrums and the genus Amaryllis itself, but also *Sprekelia, Crinum,* and *Brunsvigia,* have been variously hybridized in the course of my experiments. Thus the affinity suggested by their similarity of appearance is demonstrated, justifying at least in a measure the convenient horticultural custom of applying the familiar name amaryllis to all of them.

Peculiar interest and probably exceptional importance attaches to the fact that the first group of plants of this tribe with which I experimented included the forms of cultivated amaryllis known as *Hippeastrum Johnsoni, H. vittatum,* and *H. reginæ.* The significance of this lies in the fact that although these are plants of quite different characteristics, so that they everywhere rank as good species or fixed varieties, yet in point of fact the first one named, Johnson's amaryllis, is a hybrid that resulted from the union of the other two species.

The hybridizing experiment through which this new form was produced was made as long ago as the year 1799 by an English amateur gardener named Johnson, whose business of watchmaking had presumably given him facility in the performance of such a manipulation as is involved in the hand pollenizing of flowers.

The hybrid form thus produced not only took its place as a recognized horticultural variety, but was botanically recognized as entitled to a distinctive name. It has maintained its place alongside the parent forms during the century and more since it was first developed. Doubtless there have been some modifications in the original characteristics of the hybrid through selection, but, for anything we know to the contrary, Johnson's amaryllis retains to this day the essential characteristics of the hybrid developed by the watchmaker through the union of the two other species.

As the amaryllis is often grown from seed, it may be assumed that any given specimen of

Johnson's amaryllis in existence to-day, including of course those with which I first experimented, may be a generation or more removed from the original hybrid. Not so many generations as might at first thought appear, for the usual method of propagation of the amaryllis is by bulbs. But now and again new plants would be raised from the seed, and it would be natural that the florist should select for seedlings the best and most typical representatives of the species. So we may assume that the specimens with which I worked represented a fixed type of hybrid inbred for a number of generations, yet still carrying the new combination of hereditary factors originally brought together through hybridization of the other forms, already named as *H. vittatum* and *H. reginæ*.

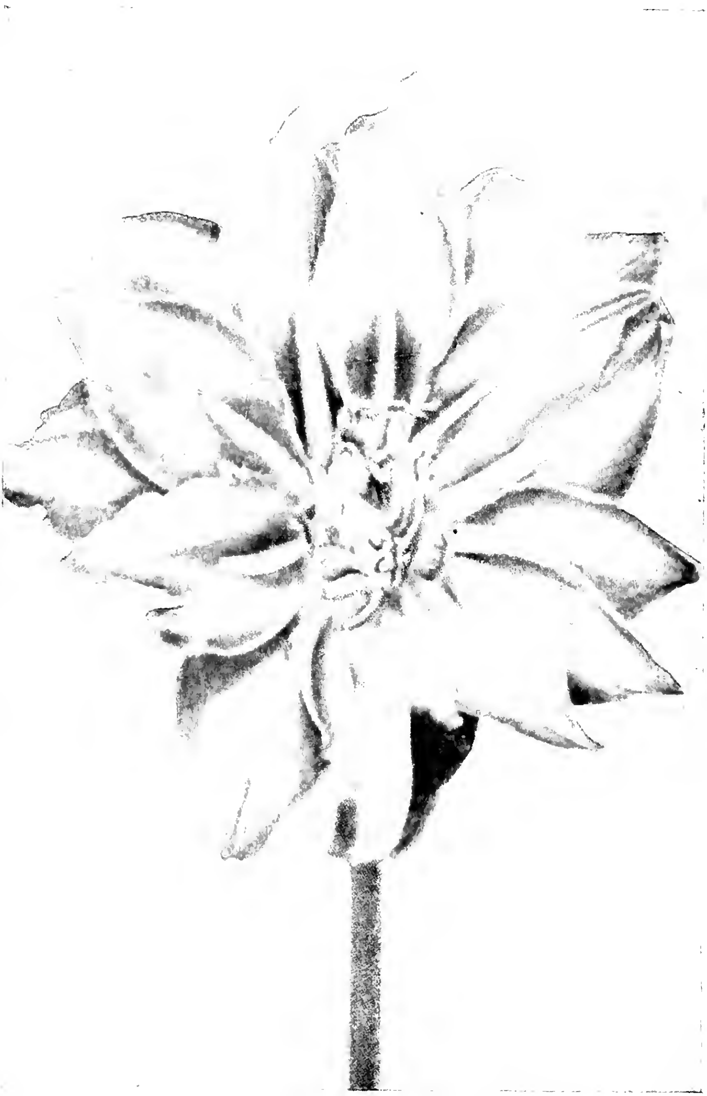
Very Mixed Pedigrees

So when I began hybridizing experiments, and crossed the *H. Johnsoni* with *H. vittatum,* I was in reality making a union of a hybrid with one of its parents.

The closeness of affinity of the two would insure ready fertilization. But, on the other hand, the balance of hereditary factors that had been attained in the hybrid would be disturbed and the immediate offspring would really represent

A DOUBLE AMARYLLIS

Among the almost numberless variations that occurred among the hybrid amaryllis colony were some that produced double rows of petals. Here is one that might readily become the progenitor of a race of amaryllis in which the petals altogether take the place of the reproductive organs, as is the case with some varieties of double roses and dahlias. Even at the present stage, this is an interesting anomaly, very much resembling a giant dahlia. (About one-half life size.)



second-generation hybrids, of which one parent was at the same time a grandparent.

The disturbing influence of this hybridization was manifest enough from the outset, and the tendency to variation thus initiated was accentuated in the next generation, which brought into the cross another species known as *H. aulicum.* It was still further accentuated in the next generation, when I used as hybridizing agent *H. reginæ,* which, it will be recalled, was one of the original parents of *H. Johnsoni.*

Thus, having started with a hybrid, I had produced three additional generations of hybrids, in which the parent forms were used and a different species added, so that my fourth-generation hybrids had the strains of three species curiously blended.

Persons who care for matters of genealogy might find it of interest to attempt to unravel the pedigrees of these fourth-generation hybrids which had for one parent the species *H. reginæ* and for the other a hybrid whose parents were born of a union of *H. aulicum* and a hybrid of *H. Johnsoni* and *H. vittatum;* recalling that *H. Johnsoni* itself is the offspring of the progenitors of *H. reginæ* and *H. vittatum.* The questions of cousinship involved in such a union are much too complex to interest anyone but the antiquarian.

At all events they need not be untangled by the plant developer. For him it suffices to recall the names and characteristics of the various species and to concern himself with such selections among their offspring as will produce races blending these characteristics in new and desirable combinations.

But, indeed, the experiment became even more complex as it proceeded to additional stages.

For by this time I was in possession of several other species of amaryllis, and these also were worked into the combination by hybridizing with different members of the fourth-generation hybrids already introduced.

The new species would be crossed with various of the hybrids to accentuate certain qualities of size of flower or color or prolific bearing; and the new hybrids thus produced would in turn be interbred, until the tangled web of their heredity was quite beyond unraveling.

Getting Results

But at each stage of such a series of experiments the plant developer of course watches for results and is guided by results.

He has learned by this time of the tendencies to variation that exist. He has gained a clear idea as to the various new races that he hopes to develop. And he is able, through selection of plants for his new matings, and through selection among the seedlings of the ones from which to save seeds, to direct the currents of heredity into desired channels.

As I have elsewhere phrased it, the plant experimenter becomes an effective part of the environment. He becomes the most important agent in that process of selective breeding through which the evolution of new forms of plant life is brought about.

In the present instance the tendency to variation that was manifested from the outset was accentuated generation after generation until, after about twelve years of work, I had a colony of mixed hybrids showing wide departures from any of the ancestral forms.

Some of the new forms had extremely large bulbs, and grew plants of exceptional strength, bearing blossoms of unusual size.

Of course I had selected for strong stalks, broad leaves, and abundant bearing and for rapid production of bulbs and ready growth, as well as for large flowers with wide petals of brilliant colors.

The original species had usually borne small bulbs, and put out only two or three offset bulbs in a season.

A BURBANK AMARYLLIS

This is a single bloom of one of my amaryllis, showing the results of selection for wide petals and flat, open flower. (One-half natural size.)

The bulbs of the new hybrids sometimes weigh more than six pounds, and the stalks that grow from them are of correspondingly increasing size and strength. And instead of putting out three or four new bulbs in a season, these hybrids sometimes multiply so rapidly as to produce a bulb every month, and in the case of some forms a new bulb every week.

That is to say, the most prolific species will produce fifty new bulbs in a year, instead of the three or four of the original species.

In point of prolific bearing, there is a corresponding contrast. The original species had seldom more than two or three stalks to a bulb, with four or five flowers in a cluster.

The new varieties often produce four or five stalks to a bulb, where they have remained in the ground for two or more seasons, with as many as twelve flowers to the stem.

The enhanced fecundity of the new forms is supplemented by their tendency to early bearing. They will sometimes bloom the second year from the seed, and on the average they bloom in three or four years. The old forms sometimes require six or eight years to come to maturity. As Prof. De Vries has said, I have pretty nearly cut in half the time from seed to blossom in the amaryllis.

But of course the most conspicuous contrast of all is in the flowers themselves. In the original species, the largest flowers seldom attain a diameter of more than five or six inches. The new giant species, as already stated, often produce flowers that are ten inches or even more in diameter.

There is considerable variation even in the same race, dependent in part on the size of the bulb from which the individual stalks grow. This should always be understood by persons who grow the amaryllis. A bulb that has been ill-treated in its first year, and has not attained large size, will not produce a large flower, even though it have the hereditary factors for large blooming.

To produce the largest flowers we must give the plant a full supply of nourishment, and thus develop a large bulb. The gigantic flowers appear only on stalks that grow from gigantic bulbs.

But of course no conditions of nourishment and no amount of forcing can produce bulbs or flowers of gigantic size unless the hereditary strains have been properly blended. And this blending, as I have just pointed out, involved years of experiment, and the bringing together of the traits of many different species.

I had experimented with the amaryllis for about fourteen years before obtaining varieties that seemed worthy of introduction. And the new giant varieties are the product of many additional years of experimentation.

The variety introduced under the name Profusion several years ago was at that time the most abundant bloomer known. Its blossoms were also relatively large, and it had many points to commend it.

But the races that have been developed more recently by selection, through the further blending of hereditary strains, excel this markedly in every regard. Indeed, the newest acquisitions to the ranks of the Giant amaryllis have advanced surprisingly upon their recent forbears.

And when the gigantic ten-inch trumpet of the new varieties are put beside even the largest flowers of the remote ancestral type, the contrast is so striking as to seem to suggest things of a quite different order.

Still Wider Hybridizations

Having reached something like the limits of variation attainable through hybridization and selection of the different species of *Hippeastrum*, I extended the experiments by crossing the new

ONE OF THE NEW CRINUMS

This is a hybrid crinum which develops a bulb of extraordinary size. Some specimens have bulbs much larger than a man's head. The flowers are large pink or pure white, often fragrant.

amaryllis hybrids with plants of other allied genera, notably with *Sprekelia* and *Crinum.*

The *Sprekelia* is represented by a single species indigenous to Mexico and sometimes called the Jacobean lily. It has long, slender, strap-shaped leaves, and a showy crimson flower of an unusual form that suggests a bird in flight.

I have grown seedlings and made selections of the *Sprekelia* more or less for twenty years, raising probably a hundred thousand seedlings, but succeeded only once in hybridizing the plant with the production of fertile offspring.

The hybrid amaryllis that made union with the Jacobean lily was my new *vittatum* type, having pale red flowers striped with white. Only a single hybrid of this union bloomed, but from this a few seedlings were grown.

The hybrid offspring of these plants of different genera had long, narrow, strap-shaped leaves much like those of *Sprekelia* (the pollen parent), but the blossoms were very much larger than those of that plant, and they had very curiously twisted petals, unlike those of either parent.

As might be expected in the offspring of plants so widely separated, the hybrids were almost infertile. As already noted, only a single variety bore blossoms, and although the blossoms were produced almost continuously throughout the summer, there was seldom any seed, and it was with difficulty that I succeeded in raising seven or eight seedlings.

In a more recent year, however, I succeeded in hybridizing many blossoms of *Sprekelia* with the pollen of one of the improved hybrid *Hippeastrum,* and secured about 800 seedlings which showed the characteristics of the other hybrids obtained by the reciprocal cross of the same species. The second generation hybrids, and also those of the third generation, showed a strong tendency to revert back to the giant hybrid species of amaryllis, rather than toward natural species.

The bulbous plants of the genus *Crinum* appear to be somewhat closely related to the Hippeastrums. There are two species known as *Crinum Moorei* and *C. longiflora* that grow in northern California, and there are other species, some of which are tender evergreens.

I have grown about twenty species, some of them of tropical origin. Numerous crosses were made among these species until I had a cross-bred strain of Crinums of ancestry as complex as that of the Hippeastrums. The seed parent of a larger proportion of the hybrids was the species known as *Crinum americanum,* but a few were grown from the seed of *C. amabilis* and *C. asiatica.* In the various crosses the traits of the species of temperate zones generally appeared to be prepotent or dominant.

Interesting hybrids were produced by crossing the Crinums, not with the members of the Hippeastrum colony (this proving impossible), but with the form of true amaryllis known as *Amaryllis belladonna.*

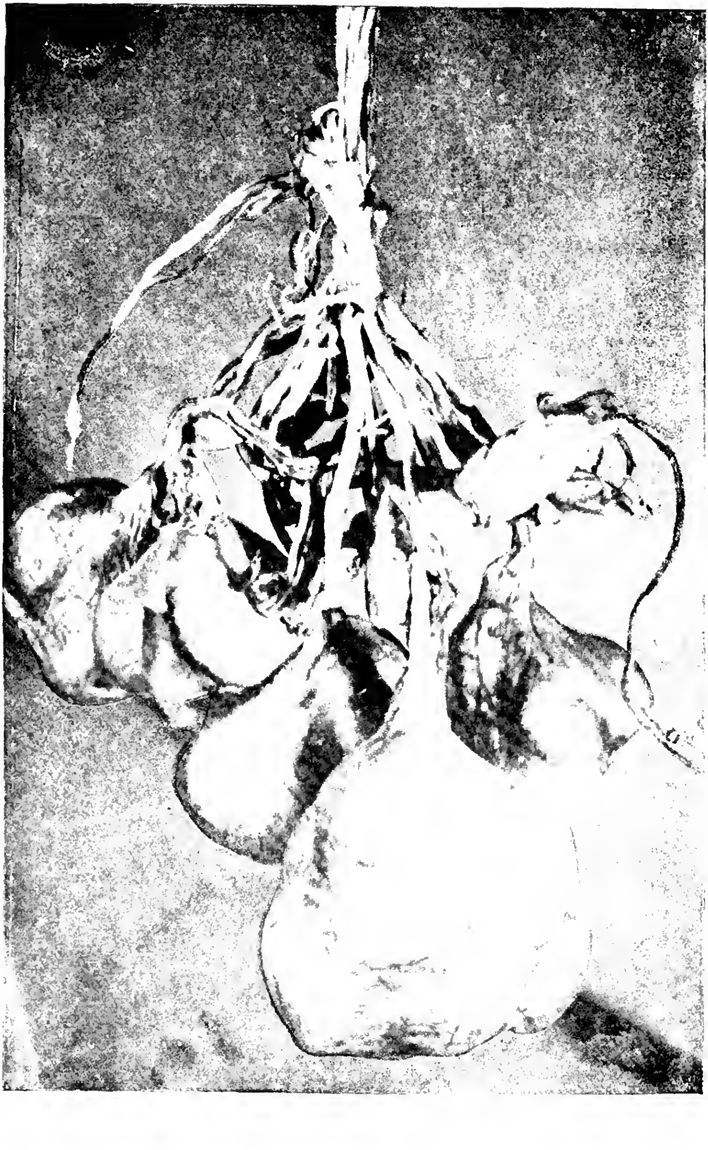
The hybrids thus produced were a very curious lot. They seemed undecided whether to take on the flat, strap-shaped leaves of the amaryllis or the tunicate leaves of the other parent. The compromise led to the production of a leaf with a long curious neck.

The flowers, like the plants themselves, may be described as a balanced combination of the qualities of the two parents. They are smaller than the flowers of the amaryllis, and more tubular, and in color they vary from white to the deepest rosy crimson, light pink being the most common color. The flowers of the amaryllis vary from rosy pink to crimson.

Although the hybrids bloom somewhat abundantly, they never produce a seed. These hybrid plants may, of course, be propagated indefinitely from the bulbs, constituting thus a permanent variety. But they evidence the wide gap between their parents in that they are sterile.

SEED PODS OF THE CRINUM

The seeds of the crinum show an extraordinary range of variation, some of them being small, whereas others are so large as to suggest miniature bulbs. The latter are so succulent that sometimes they sprout when dry and lying on a shelf. The seed pods are not red as represented here. They are pale yellow.



A Look Ahead

It will be obvious from all this that the colony of amaryllis plants, with its hybrids of intricate lineage, involving not only many species, but four genera, is a collection of plants of altogether exceptional interest.

From a mere horticultural standpoint, it is considered by experts to be the best collection of amaryllis in the world. Not only has this colony the greatest diversity of forms but the most extraordinary individual plants.

Experts of both Europe and America who have visited my grounds are agreed in pronouncing these galaxies of amaryllis far superior to any to be seen elsewhere, not only in size but in rapid multiplication and general effectiveness.

As with any plant colony that has been brought to such a degree of variability, with only relative fixation of many new combinations of characters, there are possibilities of further development that can only be realized in later generations. The number of new combinations that might be made among the complex hybrids of different types is quite beyond computation. But it may safely be predicted that some of these combinations will produce results even more striking than any hitherto attained.

As an inkling of some of the expected developments that as yet are only at their beginnings, I may add there is among my plants one that bears an eighteen-petaled flower, and which is otherwise exceedingly handsome, and there are several others with a double row of petals. This did not breed true as to the production of excess petals, but there is little doubt that by selective breeding it will be possible to produce a double amaryllis which will be an entire novelty.

In the matter of hardiness also, there is opportunity for great improvement. My amaryllis plants are grown out-of-doors, the seedlings being started in the greenhouse in boxes very much as other bulbous plants are started, but not in a high temperature. There is opportunity, however, to increase their hardiness by selection, or by crossing with some hardier species.

It is true that the hybrids of *Crinum* and *Amaryllis* have hitherto been sterile, but there is reason to hope that other combinations might be found that would produce fertile offspring.

These and other like developments, however, await the experiments of future seasons and future experimenters. But, even as it stands, the colony of bulbs of the amaryllis and its allies constitutes one of the most interesting groups of plants anywhere to be found.

PRODUCING AN ENTIRELY NEW COLOR

And Other Important Work with the Poppies

FOR some reason blue is not as common as other colors among flowers.

There are notable and conspicuous exceptions, of course, but for every species of blue flower in nature there are hundreds of flowers that are yellow, red, or white.

Presumably the color blue does not attract the eye of the insect so strikingly as do the other primary colors. Flowers are not green for the obvious reason that, since leaves in general are green, flowers of that color would blend with the foliage, and thus defeat the primal purpose of the floral envelope.

And, no doubt, blue is a color nearer to green in its hue or general aspect than are the reds and yellows.

So it is perhaps not surprising that natural selection has weeded out the blue flowers and given us an abundance of red and yellow and white ones.

Of course, there may be some underlying reason associated with the chemical character of the different colors that helps to account for the relative scarcity of blue flowers. But, as to this, no one at present has any definite knowledge, for the chemistry of the colors, and the underlying differences between the colors in the petals of flowers, are very little understood.

But, whatever the explanation, the fact of the scarcity of blue flowers is patent enough. Where a flower has adopted the blue color, it may hold to it tenaciously. But, on the other hand, there are thousands of blossoms that show great variation in color, ranging through the various tones of scarlet and crimson and pink and orange and yellow, apparently quite without discrimination, yet avoiding blues of every type.

A Blue Poppy

Conspicuous among the flowers that show this wide range of variation in color, and yet never by any chance have been known to produce a blue flower in the state of nature, is the familiar poppy.

So the production of a blue poppy, through a long series of selective experiments, may be considered one of the most striking of the minor plant developments accomplished here. There is no record of a true blue poppy ever having been produced elsewhere.

The blue poppies bloom toward the last of May or early in June each year, furnishing a spectacle that never fails to excite the interest of visiting botanists and florists.

The story of the production of the blue poppy is a comparatively simple one as to its chief outlines. That is to say, the work that was directed exclusively to the production of a flower with this color was carried out without any complications of hybridizing, solely as a problem in selection.

A measure of success was attained in the course of five or six years after the problem had definitely presented itself.

But, on the other hand, it should be explained that the specific idea of developing a blue poppy came only as a sequel to a long series of very arduous experiments in selective breeding through which the ancestral stock that finally produced the blue poppy had been developed. And it is more than probable that the preliminary experiments, although aimed at quite different purposes, were absolutely essential to the segregation of hereditary factors in the plants

A NEW SHIRLEY POPPY

The Shirley poppy is a flower developed within recent years by an English clergyman who found a solitary flower of the scarlet corn poppy that had a very narrow edge of white. By selective breeding he produced the poppies of many colors now familiar under the name of Shirley. The specimen here shown illustrates the tendency of the flower to take on new color variations and a very large size when crossed with the Tulip poppy (Papaver glaucum).

of my poppy colony that made possible the final development of the flower with the anomalous color.

Therefore, it will be necessary, as preliminary to a specific account of the quest of the blue poppy itself, to give somewhat in detail the story of the development of the ancestral strains of poppies of varied but more usual colors.

Origin of the Shirley Poppy

The poppy from which the blue flower was developed is known as the Shirley poppy.

This is one of the most interesting and beautiful varieties of the species *Papaver rhœas*, the corn poppy of Europe.

The peculiarity of the Shirley in which it differs from the wild form of field poppy is that it varies in color from the original red to a pale pink and even to a pure white; and that the original black central portion of the flower has been changed to yellow or white. The last-named characters are the distinctive ones. The true Shirleys never have the smallest particle of black about them. They may be scarlet or pink or white or variously flecked. But they have no black about them, and they were never yellow, until pale yellow and pale orange shades have recently arisen.

This beautiful variety gains enhanced interest when we learn that it was developed as recently as about the year 1880, in the garden of an English clergyman, the Rev. W. Wilks, through a series of selective experiments of precisely the character so often illustrated in the course of our present studies.

It appears that Mr. Wilks discovered in a field of the corn poppy of the usual scarlet color, a solitary flower that had a very narrow edge of white. He marked this flower, saved the seed of it, and the next year carefully watched the seedlings. Out of perhaps two hundred he found four or five on which all the flowers were edged with white.

The best of these were marked, and their seedlings were selected from in turn.

In successive years a large proportion of the flowers gained an increasing proportion of white to tone down the red, until they arrived at a quite pale pink, and finally one plant was found that was pure white.

The attempt was then made by similar selection to change the black central portion of the flower to yellow or white, and in due course this also was accomplished.

The new strain being fixed by selection, the Shirley poppy, which has come to be one of the most popular of flowers, was given to the world.

It appears then, that the Shirley poppy is a variety that has been specially selected within comparatively recent years with an eye to the one problem of color modification. It therefore represents a strain of plants in which there is a curious mingling of hereditary factors for color. It is a fixed variety, at once recognizable, yet the different flowers that resemble each other to the point of approximate identity as to form and botanical features may be scarlet or pink or white or variegated, and all these colors may be represented in the plants grown from a single lot of seed, and sometimes in a single individual flower.

Even as to the matter of the black center which characterizes the original corn poppy, the Shirley shows a tendency to reversion. Now and again flowers appear that have black spots at the base of the petals. These, however, are rigidly excluded by the florists in selecting seed.

Other marks of tendency to variation in the Shirley are the uncertain length of the stem, which may be very short or very long, and a propensity to doubling of the petals, which is regarded as a defect. Moreover, there is sometimes manifested a tendency to a crimson hue that is regarded as reversional, and has to be eliminated by the careful flower grower.

Perfecting the Shirley Poppy

All these marks of a tendency to variation, together with a history of the development of the flower, marked the Shirley as a plant suitable for further experimentation. So about twenty-five years ago, at a time when the Shirley was a comparatively new flower, I commenced a series of experiments with this variety, securing seed from every available source.

I was somewhat astonished and disappointed to find that, in spite of the somewhat diversified color scheme of this flower, there was a very striking uniformity among the plants produced from various lots of seed. Everywhere there was a strong tendency to revert to the original scarlet color, but otherwise the colors were fairly well fixed. Attention was chiefly attracted to the form of the petals, however, which seemed rather lacking in gracefulness, being too flat and without character.

With the thought of modifying the petal and thus beautifying the flower, I commenced the most rigid selection, choosing the first year only four or five plants out of many thousands, and from the progeny of these reselecting from season to season.

The flowers were chosen that showed the lighter shades of scarlet, crimson, and pink, and those that were altogether white.

Attention was given also to the selection of larger flowers, and in particular to those that had the most delicate petals, and firmness of texture and any suggestion of waviness was joyfully welcomed.

For many years this selection was continued, raising large quantities of poppies, and having the aid of four or five men in marking the selected flowers in the field for an hour or two each morning during the blooming time, that no specimen showing favorable variation should be overlooked, and that no plants showing reversion be left.

At first the progress was very slow. It was easy to find specimens that were semidouble and those that had the black spots. But there was very slight tendency to crimping of the petals.

As usual in such cases, however, there came a time when progress seemed much more rapid.

Thenceforward the work was encouraging and full of interest, and in a few years more a most beautiful strain of poppies had been pro-

ANOTHER NEW SHIRLEY POPPY

The Shirley poppy differs from its wild progenitor in that it has varied from the original red color to a pale pink and even to a pure white; and in particular in having lost the black central portion of the flower that is so characteristic in the wild corn poppy. The true Shirleys are characterized by the entire absence of black—they have not the smallest fleck of it about them. But the mixture of color factors is revealed in the striking tendency to variation in unpredictable directions when crossed with other species, followed by rigid selection for a definite purpose.

duced which presented almost in ideal combination the various qualities for which I had been selecting. Those that were not pure white showed an astonishing variety and a beautiful blending of the more delicate shades of red and pink and rarely salmon.

The plants were graceful in form and of uniform height, and, most important of all, the petals of the flowers were almost of the texture of tissue paper, yet of firm texture, and artistically waved and crinkled, in strong contrast with the smooth petals of all the original varieties.

This plant was introduced through an Eastern and European seedsman as an "Improved Strain of Shirley Poppy," and later when still further improved as the "Santa Rosa Strain of the Shirley Poppy." The modifications are so striking that various horticulturists have suggested that the plant is entitled to rank as a wholly new variety. But I preferred to recognize the variety from which the new plant had been developed by retaining its name.

The Coming of the Blue Poppy

I have repeatedly mentioned that no flower or fruit is or can be developed beyond possibility of further improvement. However closely a new form may approximate the ideal at which the plant developer aimed there are always variations that suggest new possibilities that perhaps were not contemplated at the outset of the experiment.

And the improved Shirley poppy was no exception to this general rule. As work continued with the new flower, the form of its petals modified until they were exquisitely delicate, and its colors blended until the most artistic and delicate shades were predominant, attention was attracted one day to a specimen growing among the thousands that revealed a shade different from any other previously seen.

On inspecting this flower I seemed to detect, underlying the normal color, a smokiness suggestive of a half-concealed blue pigmentation.

Naturally this was carefully guarded and the seeds of this plant preserved and sowed by themselves the following season to make the basis of a different series of selective experiments.

The history of this new colony duplicated that of other groups of plants undergoing selection. Year by year an increasing proportion of flowers with the smoky hue were found and always among these a few that revealed the obscure blue a little more clearly.

Finally, after several years of selection, I had a strain in which about one-third of the plants bore flowers of various shades of blue, some smoky and others with fairly clear, if not very bright, blue color.

The few flowers that were pure blues were naturally selected to continue the experiment. But their seedlings for the most part failed to reproduce the color.

Selecting year by year, however, among the individuals that produced flowers of the purest blue, the strain was gradually fixed until each year a plot of poppies appeared that, seen from a little distance, presented the aspect of uniform blueness. This, of course, is the patch referred to as exciting the astonished comment of florists that visit my grounds at Santa Rosa about the first of June each season.

But the effort to establish the blue variety as a fixed type through inbreeding and selection has been fully achieved.

Were the poppy a plant that is propagated by root cuttings or any other of the common modes of division, the blue variety would long since have been given to the world. But as it is necessary with this plant to develop the variety until it will breed true from seed, I have been obliged to continue the experiment at least ten years longer than would otherwise have been necessary.

Now, however, the blue poppy is an accomplished fact. Its production constitutes one of the most striking color modifications made through artificial selection.

Creation or Reversion?

So far as is known, there was never an ancestor of the Shirley poppy that was blue. So here we have an illustration of an experiment that is radically different from any that we hitherto have had occasion to describe.

The bringing out of this color constitutes a development of radically different character from the mere modification of color of a flower within the range of the color scheme of a species, or of allied species, or even of allied genera.

The development of a Shirley poppy that is yellow, for example, which was a second task that a German experimenter set himself, would be comparatively easy, because yellow is a more common color with members of the poppy family, and a tinge of yellow is not unusual.

I have myself developed and introduced strains of Shirley poppies of salmon or deep yellowish pink color. These include various shades of salmon and light scarlet, but with no trace of crimson or of darker colors of any kind.

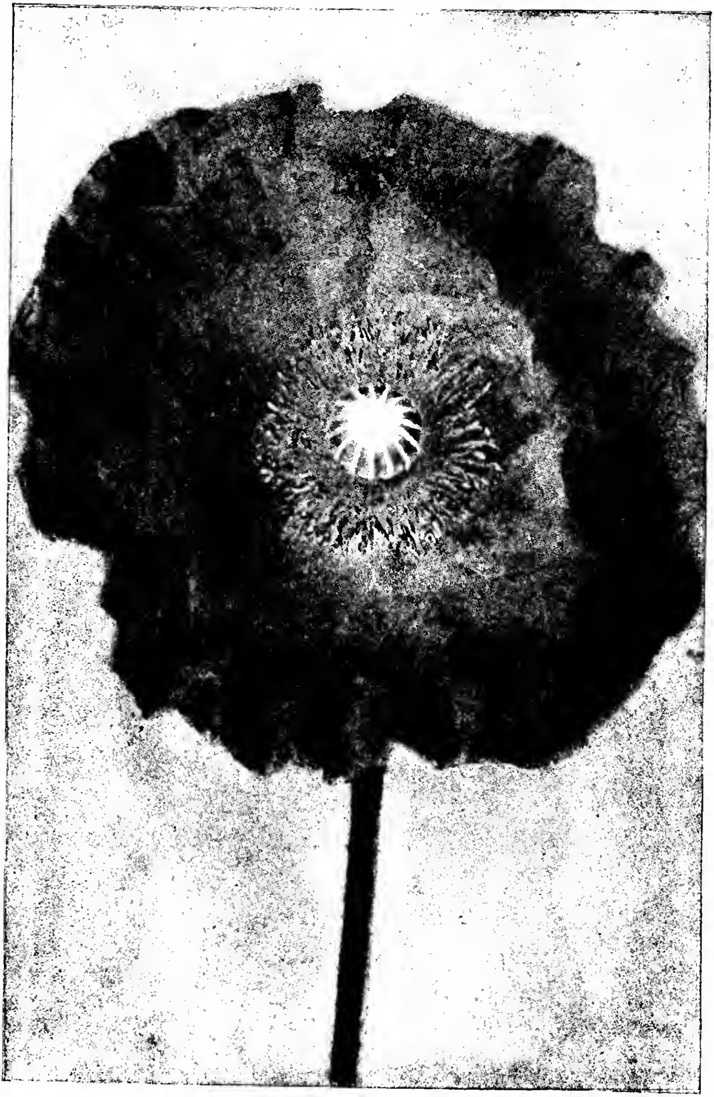
This flower, which had been selected also for size and crimping of petals and gracefulness, as well as for color, was introduced under the name of "Burbank's Sunset Shades of Shirley Poppies."

But this new variety is mentioned only to point the contrast. No such amount of work was involved in its production as that which attended the production of the blue poppy, because yellow pigments are in the heredity of the poppies in general, and must have been manifested among the ancestors of any given strain of poppy within relatively recent times.

The affinity between the yellow and red, for example, in the case of the poppy, is clearly enough demonstrated in the experiment, outlined in an earlier chapter, in which I developed a race of crimson California poppies (*Eschscholtzia*), the parent species being, as is well known, bright yellow in color. It will be recalled that the new crimson flower was developed by selection through successive generations from a specimen that showed a little line of crimson, like a streak or thread of another color, lengthwise of a single petal.

ANOTHER NEW POPPY

Once a flower manifests a tendency to vary there seems to be no limit to the range of its variations. It would be hard to say just what combination of hereditary factors in the germ plasm of the original Shirley led to its peculiar departure from the traditions of its tribe. But selective judgment enabled these submerged color factors to make themselves manifest, with the result that a strikingly modified flower was produced in the course of a few generations. This blue Shirley poppy cost me nearly twelve years of most careful selection.



California poppies of various other colors were developed in the same way, but no blue shades have ever appeared among them.

In the case of these California poppies, then, the relative ease with which the flowers were changed from yellow to crimson would seem to suggest that the latter color lies but slightly submerged, if the expression be permitted, in the hereditary stream, ready to come to the surface if the thin overlaying current of yellow can be removed.

Another illustration of the linking of yellow and crimson in the hereditary scheme of the poppies is given by an experiment in which I crossed two distinct species of poppy, one having flowers of pale yellow, the other pure white.

The hybrids without exception bore flowers of a clear crimson color. There was not a white one nor a yellow one among them.

Another interesting color modification in the case of the poppy was that which produced the so-called silver-lining poppy. In this case I discovered a flower in which there was a white line between the black center and the crimson part of the petal. This line was widened by selection until the petal was white with black center, the white extending just over the outer edge of the petal, the rest of the back of the flower being crimson.

It may be interesting to recall in this connection a series of experiments in which the only true California poppy (*Papaver californica*), a rare and little known plant, was modified by selection, working with a five-petaled sport, until a variety was produced that uniformly had six petals. The size of the flower was also greatly improved by selection; but the color of the original—a pale orange—has so far refused to budge.

Yet another poppy modification of interest was that through which the Iceland poppy was developed until its seed capsules had fifty-six proliferations instead of the original one.

The Varying Dominance of Colors

The story of the color variation in poppies, as illustrated in the development of the Shirley and its modifications, and in the selective and hybridizing experiments just related, furnishes fairly tangible evidence that the scheme of pigmentation of a flower is of somewhat less fixed or fundamental character than the various characteristics of form and leaf system and breadth and arrangement of petals and stamens and ovules, that are depended upon by the botanist in determining plant relationships.

The fact that a certain flower, for example, may vary in color from bright scarlet to pure white, and from salmon to blue, while still retaining the botanical characteristics that would lead any florist to classify it as a Shirley poppy, in itself demonstrates the comparative unimportance of any particular color in the scheme of plant economy.

There may be special conditions that make a red flower fit into its environment a little better than a yellow flower, or vice versa; but either red flowers or yellow ones or pink ones or white will attract the insects, and thus fulfill the purpose for which color in the flower has been developed.

That, doubtless, explains why it is relatively easy to modify the color of a flower, within certain limits, and—what amounts to saying the same thing—why the same species of flower may so often be found presenting different colors or shades of color in different localities, or under varying conditions of cultivation. But perhaps the chief interest of the entire matter of the coloration of flowers, and specifically the chief interest of such a development as that of the blue poppy, is found in the suggestions given as to the underlying principles of heredity involved in color transformations.

A HYBRID POPPY

This graceful, everblooming, perennial hybrid poppy was produced by crossing the oriental perennial poppy with the annual somniferum. The flowers have the grace of the annual, the rich colors of the oriental, and bloom continually all summer, while neither parent blooms more than a week or two. (About one-eighth natural size.)

It would seem as if we are justified in concluding from the evidence that the hereditary factors for the production of many different pigments are mingled in the germ plasm of any given species of flowering plant.

If one color predominates over another in the flower, it is because its pigment is dominant over other pigments, and the study of color dominance furnishes interesting side lights on the question of the hereditary transmission of unit characters.

In the animal world, for example, where the study of the heredity of color has been carried out pretty extensively in recent years, there are interesting combinations showing a somewhat more complex character than any that we have hitherto examined. We have seen that in the case of the guinea pigs black pigment is dominant to white, so that when a black guinea pig is mated with a white one the offspring are black, but the recessive trait of whiteness reappears in one in four of the progeny of the second generation.

But it appears that in these animals, and similar ones that are subject to wide variation of color, there are curious complexities of heredity, nearly all of which, however, so far as studied, fall within the scheme of "Mendelian" transmission.

Thus it is found that in the case of mice, for example, whereas blackness of coat is dominant over whiteness, just as in the case of the guinea pigs, blackness itself may be overlaid, as it were, and entirely obscured by the presence of factors for gray coating, and it further appears that yellow pigment may dominate the gray coat as well as the black.

A further complication occurs in that an animal that is neither yellow nor gray nor black may be chocolate in color. And it is only in case this color also is absent that the mouse will be white.

Moreover, if the factors for chocolate are absent, the factors for grayness and blackness may neutralize each other, and exist in what is called a masked condition, neither one being able to make itself manifest on account of the presence of the other, because both are dominant factors; so that the mouse will be white, yet will carry the factors for grayness and for blackness masked in its germ plasm.

When the chocolate factors are present, however, in addition to the factors for blackness and grayness, the presence of three dominant color factors has the curious effect of enabling one of them, in this case gray, to make itself manifest.

So the chocolate factor is necessary to produce a gray mouse; and the chocolate-colored mouse will appear only when the factors for grayness and blackness are absent.

This rivalry of dominant color factors, with subordination of one to another, even though both are dominant over whiteness, has previously been briefly referred to, and it has been noted that, for convenience in describing the condition, biologists have come to speak of a factor that thus subordinates another, in the sense in which gray subordinates black in the coat of the mouse, as *epistatic;* the subordinated color factor (in this case black) being said to be *hypostatic.*

These terms are of obvious convenience, being somewhat parallel in their application to the Mendelian terms dominance and recessiveness, yet being quite distinct, as we have seen, inasmuch as they apply to the relations of factors that are both dominant, yet which refer to the same quality and hence cannot both prevail.

Mixed Factors in the Poppy

Our studies of inheritance of color in the poppies suggest that closely similar relations exist among the pigments of the flowers.

The exact relations of reds and yellows and pinks and blues have not been carefully worked out on a comprehensive scale, as have been the pigment relations of the coats of mice and

THE BURBANK ART POPPIES

These are only a pitifully few samples of the most beautiful race of poppies ever produced, and one which is widely known for its especially artistic flower in a hundred new shades with crimped petals and unusual lasting qualities.

rabbits. But the evidence seems to suggest that the relations of red and yellow, for example, in the case of the poppy, are somewhat comparable to the relations of gray and black in the coat of the mouse.

That is to say, both of these are dominant to white, but one of them is epistatic to the other.

It is probable that red is superior in dominance, or epistatic, to yellow, and hence that a poppy will be yellow in color only when the factor for red pigment is either absent or masked.

The experiments that led to the production of the blue poppy suggest the possibility that blue pigment may occupy some such place in the scheme of coloration of the poppy as that occupied by the chocolate color in the scheme of the mouse's coat. In that case, a poppy would be blue only in case the color factors for red and yellow were both absent. And a poppy would be white only in case the color factor for blue was absent, although there might be present color factors for both yellow and red in the condition of equilibrium which we have spoken of as masked. A dingy white flower might contain a trace of blue.

This supposition might explain the case of the yellow poppies crossed with the white ones, in which the hybrid offspring were all crimson in color. The hybridizing in this case may be supposed to have brought together latent or masked factors for red (present in the white flower), the mating of which gave that color dominance, and enabled it to assert itself, while the yellow factors were unable to assert themselves, yellow being hypostatic to red.

Suppose, for example, that the yellow poppy bore factors for yellow and blue; and the white one factors for red and yellow. The combination would bring together red, plus yellow, plus blue; and red would be manifest, the other colors being masked. Recombinations should be expected in the next generation.

But the actual conditions are probably a little more complex even than here suggested. The smoky character of the blue poppies, especially in their earlier forms, seemed to suggest the presence of a factor for blackness. And, indeed, the fact that black pigment constantly tends to appear in the poppies shows how potent an influence this is. So, when the entire hereditary color scheme of the poppies is untangled, it will probably be found that there are dominant factors for red and yellow and black and blue corresponding more or less to the yellow and gray and black and chocolate pigments of the coat of the mouse; and that these are mutually dependent on one another in an intricate fashion, the full explanation of which would give us a far clearer comprehension of the mysteries of the color transformation in the poppy and in other flowers than anyone can claim to have at present.

It is because of the new light they throw on this problem that experiments that led to the production of a blue poppy seem to have unusual interest and importance. But long series of additional experiments involving much expense and many discouragements will be necessary before the exact relations of the different pigments in the poppy, or in any other flower, will be fully understood.

A DAISY WHICH RIVALS THE CHRYSANTHEMUM

And Other Improvements in Daisies

THE story of the origin of the Shasta daisy was told in an earlier volume.

It will be recalled that this new flower, differing so widely in size and form and appearance from any daisy hitherto known, is in effect a new species produced by the combination of three species of wild Chrysanthemums (and a fourth variety) that came respectively from Europe, from the eastern United States, and from Japan.

The long series of experiments through which the European and American species were first hybridized, and the Japanese species subsequently brought into the combination, followed by new crossings and selections season after season through a long term of years, has been told in detail. Here it seems desirable to refer to more recent modifications of the Shasta, giving some specific hints as to its cultivation, and to review the work done with certain other daisy-like plants—to which also reference was made in an earlier volume—with particular reference to the interpretation of the results accomplished, in the light of the new information supplied us by observation of other series of experiments.

First a few words as to the progress of the Shasta daisy, which, as we have learned, not only constitutes virtually a new species, but has given rise to a great variety of modified forms, all of them Shasta daisies, yet differing as markedly among themselves (in form at least) as, for example, different races of roses or poppies or dahlias differ.

The racial strains of the three original parent species have been so recompounded, and, as regards their broader outlines, so truly fixed in the new species, that no one who sees a Shasta daisy can fail to recognize it as a Shasta—just as we recognize a rose or a poppy or a dahlia—even though the particular specimen under observation differs very radically as to size and form and arrangement of petals from any one of the half dozen varieties that may be under observation at the same time.

And the meaning of all this has been made clear to us in our studies of other forms. The separation of unit characters through hybridizing different species, and the recombining of these characters in the offspring of the second and subsequent generations, which is so vividly illustrated in the case of the Shasta, has been illustrated also in scores of other cases, until the principle involved has become so clear and obvious that no one is likely to overlook it.

Therefore, it is not necessary here to recapitulate the details of the series of hybridizing experiments through which the Shasta daisy was evolved. We shall be concerned with a few practical details as to the cultivation of a plant which is making its way into gardens everywhere, and which is sure to increase in popularity as the years go by.

Spread of the Shasta

Probably no flower ever introduced has been more thoroughly appreciated and more rapidly and widely disseminated than the Shasta daisy. Owing to its hardiness, it can be grown anywhere from Alaska to Patagonia, and it requires almost no attention, except a biennial division of the clumps into numerous small plants, each piece of which will soon make a vigorous new clump.

It is now widely grown throughout both temperate zones, and is rapidly becoming popular as a park and garden plant. It is greatly in de-

A SEMIDOUBLE DAISY

The tendency to variation induced in the progenitors of the Shasta daisy through hybridization is manifested in a great variety of ways. Here is a specimen in which the ray flowers are multiplied in number and some of them curiously altered in form. Such a specimen as this became the progenitor of an altogether double Shasta, the ray flowers gradually supplanting the seed-bearing organs at the center of the flower.

mand for interior decorations, partly because its cut blossoms will last fully two weeks, whereas those of dahlias, roses, and lilies usually become quite unsightly after two or three days.

Under no circumstances should the Shasta daisy be grown from seed, unless it be for the purpose of producing new varieties. No one would raise Chinese or Japanese chrysanthemums, roses, or carnations from seed, and hope to obtain the beautiful forms and colors peculiar to the selected plants. Strains produced by hybridizing vary more or less; upon this, of course, depends their chief value to the gardener who wishes to produce new varieties; but from the very fact of their mixed heritage these plants will not breed true from seed.

But they are readily propagated in any desired quantity from the root of the mother plant.

Reference has been made to the double forms that have appeared among the seedlings. Some of these bloom so freely as to destroy the vitality of the plants, unless some of the buds are removed. Other varieties have appeared with long, slender, laciniate rays, giving the blossoms a soft, feathery appearance; others, still, with curious twisted ray-flowers, or with long, tubular, or drooping ones, or those that are curled inward and upward, producing beautiful, cupshaped blossoms; and all these in double form like roses, carnations, or dahlias.

All these curious forms can be reproduced indefinitely by division, but not one time in ten thousand can the best ones as yet be reproduced from seed.

Practical Hints as to Culture

The Shasta daisy, though an exceptionally hardy plant, is, to a certain extent, sensitive to the conditions of its environment, and in order to secure the most thrifty plants and the most attractive blossoms it is necessary to follow certain rather definite rules of culture. The best results follow a division of the plants about every third year. If it is desired to develop strong, vigorous plants from the start, the old plants should not be allowed to bloom, else the cuttings taken from them will possess but scant reserve vitality.

The plants should be divided into pieces as small as possible, care being taken to leave a bud and a few leaves and roots attached to the cutting, though the roots may be omitted, provided the divisions are properly treated. The long slender leaves should be cut back about one-half their length, so that they do not take too much moisture before the roots develop. After rinsing the cuttings in cold water they should be closely planted in a bed of sifted sand, indoors or out, according to climatic conditions, though out-of-doors is better.

In order to settle the soil around the cuttings, they should be drenched with water, and a uniformly moderate supply of moisture should afterward be maintained.

If these instructions are followed, even the smallest, most unpromising cutting may develop into superior plants. When the slips are strongly rooted, they should be placed in a sunny place in rows eighteen inches to two feet one way by three or four feet the other. They should be thoroughly watered and treated like other garden plants. During July, August, and September each of the original cuttings should bear from twenty-five to fifty large, beautiful white blossoms. During the second season the best varieties should produce from one hundred to two hundred blossoms, measuring ordinarily from three to six inches in diameter.

For the production of new varieties, Shasta daisy seed may be sown thickly in boxes of sandy soil or in out-of-door beds in California. If the seeds are those from the improved varieties, the resulting seedlings will bloom the first season, although the older varieties did not bloom till the second season, and then not as abundantly as these do the first. But the seedlings will form a motley company, many of them reverting to ancestral forms and departing widely from the characteristics that have made the fame of Shasta daisy.

Could the Shasta Be Fixed?

The question is one that is not without practical interest. For there is obvious convenience in being able to grow an ornamental plant from the seed, even though it be possible to propagate it indefinitely by division. A small package of seeds may be shipped far more readily than roots or entire plants, and no doubt a large number of people will grow a plant from the seed who will not take the trouble to transplant roots or work from cuttings.

So the question as to the possibility of fixing the Shasta is not without some practical importance. But the question also has a theoretical interest in connection with the general problems of the plant developer as applied not merely to this species but to many others.

Our studies of many forms of plant life have taught us that the cultivated varieties of flowers, fruits, and vegetables are so complex as to their heredities that—except in the case of certain annuals—they do not breed true from the seed, and are not propagated in that way. Yet, on the other hand, we have seen that it is possible to fix new races by careful selection, and the principles according to which the experimenter works in effecting such fixation have been pointed out again and again.

Making application of the knowledge thus gained to the case of the Shasta daisy, we need have no hesitancy in asserting that it would be possible to fix races of this plant so that they would reproduce their type with approximately the certainty from the seed as do, for example, the original parent forms from which they spring. But this task is as unnecessary as would be the task of fixing roses, carnations, or chrysanthemums.

If inquiry is made as to the length of time required to effect such fixation of type, the answer can be given with a fair degree of certainty. Working along usual lines, by selecting the best specimens in a large company and in the successive years the best specimens among their progeny—extending, in other words, the method of selection through which the new races were originated—it would probably require from six to ten generations of selection to make sure of securing a specimen from which the disturbing hereditary factors had been eliminated

LACINIATED PETALS

Sometimes one may find among ox-eye daisies a specimen that has a tendency to fluting of the ray flowers, but no one ever saw flowers like these until they were produced on my grounds. (One-half life size.)

by selection so that the factors that remain are those that produce the qualities that we desire to retain.

Let the seed of each individual plant of these type specimens be sown in a separate plot; and in due course isolate each seedling so that each individual plant is self-fertilized. We shall then find that among the offspring of each plant there is the utmost diversity, but it will appear, in the next generation, that there are some plants that breed true to type and others precisely similar in appearance that produce diversified offspring.

The suggested manner of selecting by isolation of individuals merely enables us to go more directly to the goal. It does not differ in principle from the ordinary method of selection. But the isolation of each individual, so that its traits may be separately tested, enables us to reach the result in a shorter time.

So the experimenter who wishes to fix a race of Shasta daisies may with confidence go about the work along precisely the same lines that were used, for example, in the production of the wild *Heuchera* with crinkled leaves—the method, for that matter, through which the races of Shastas were themselves developed after hybridization had supplied the material for selection.

Colored Daisies

It will be recalled that final hybridization through which the Shasta daisy was produced was made chiefly with an eye to the removal of the last tinge of duskiness and a greenish yellow shade that is more or less present in all white flowers, leaving a flower of snowy whiteness.

It will be understood, also, that this quality of whiteness characterizes all the new races of Shastas—except one that has been bred for yellowness. The number of florets and their arrangement and form and size have been modified indefinitely, but these modifications do not in any way affect the color, except in case of one that showed a tendency toward yellow, and from this numerous yellow varieties, single and double, were developed. This color, however, fades in sunlight, and blanches in a few days. Aside from this, all Shasta daisies are characterized by their snowy whiteness. The improved varieties rival the variously modified chrysanthemums in size and form and in flexibility of florets; but they do not imitate the chrysanthemums as to variety of color.

Possibly some varieties of Shasta may be modified in other directions as to color. One already shows pink on the outside of the ray flowers. One was found last year that had a faint shade of pink, and seed was saved. A pink Shasta daisy is therefore in prospect.

There are other species of daisies, however, that show color variation. The whiteness of the oxeye daisies both of Europe and America, and of the French marguerites, seems so typical that at first thought it appears anomalous that any daisy should depart from the traditional color.

But, on the other hand, our studies of flowers have shown us that color is the least fixed characteristic of the floral envelope, and, reasoning from analogy, it would be rather surprising if there were not races of daisies, more or less closely related to the parents of the Shasta, that have colored blossoms.

The Paris daisy (*Chrysanthemum frutescens*) has one lemon yellow variety; and there is a so-called daisy, indigenous to South Africa, that has blossoms of a rather brilliant orange. This so-called African daisy (*Dimorphotheca*), however, is not very closely related to the Chrysanthemum. The reader will recall a chapter of the first volume in which the story of this flower is told. It will be recalled that there is a closely allied species of *Dimorphotheca* from the same region of South Africa that differs from the orange one, chiefly in the fact that it is white.

It will further be recalled that when these two species, the orange and the white, have been hybridized, the hybrid offspring shows an astonishing diversity of color.

Not only oranges and yellows of many shades, but shades of purple and red also appear. It was by selection among the red hybrids, as will be recalled, that a so-called African daisy of a beautiful and uniform pink color was developed.

It will further be recalled that among the hybrids were some which showed, on the backs of their petals, streaks of purple, showing that factors for blue color, as well as factors for yellow and red, are present.

The interest of this experiment, as a mere illustration of a new race developed by hybridization, is not inconsiderable. But the chief interest of the experiment centers about the production of new colors which appeared to be alien to the hereditary traditions of either of the African tribes.

Properly interpreted, the facts brought to light by these experiments fall in line with a large number of observations having to do with the colors of flowers, and give intimations of an interpretation of the entire subject of floral coloration.

In attempting to interpret the facts, we should bear in mind what was learned in the preceding chapter as to the variable coloration of the poppies, and we shall have occasion to draw other illustrations from plants of many different types. We have found reason to believe that most flowers owe their color to a mingling of pigments, or at all events have in their hereditary strains the factors for many different colors, somewhat as even the purest tones on the canvas of the painter are usually the result of the blending of diverse pigments.

We shall find reason to believe that even the white flower is not as a rule white because it lacks the factors for color pigmentation, but because it mingles these factors in such a way that they mutually antagonize, or neutralize, or "mask" one another.

In this view, then, the production of a pink African daisy through the hybridizing of an orange and a white one may be regarded, not as an anomalous phenomenon, but as a typical one —albeit the experiment has a good measure of interest none the less.

Variation of Color in Flowers

The fact of color variation in the flowers is, as just stated, too obvious to escape notice of the

A BOUQUET OF SHASTAS

In this variety of selected Shasta, the petals have been greatly multiplied, and the inner ones have taken on a fimbriated character that is peculiarly attractive. The flowers have not quite given up the habit of seed production, however, so further development was possible in the course of successive generations. (About one-sixth life size.)

least observant. Many people, however, are unaware of the wide range of variation shown among wild species.

It is sometimes assumed that color variation is due to the cultivation of plants; and, of course it is true that cultivation has resulted in developing races of flowers of diversified colors. But it is not to be supposed that these colors could have been developed in the short period during which the plants have been under cultivation had not the materials for color variation been present in the various hereditary strains.

And it requires but the briefest search among wild flowers to show that color variation is by no means exceptional, but is, on the other hand, quite the rule here, even as among cultivated species. With a wild species, to be sure, there is usually preponderance of one color or another, because natural selection tends constantly to fix or accentuate one character and to minimize or eliminate another. In some respects the guide marks on the flower seem as important as the color itself.

But that even under natural conditions it may not make a vast difference to the plant whether its advertising floral envelope, to attract the attention of insects, is of one color or another, is suggested by the frequency with which we find plants of the same species putting forth flowers different in hue.

We cite a few instances, taken quite at random. They will suggest the extent to which one color may do service for another in the same species; suggesting also the probability that hereditary factors for all the colors manifested by different specimens of a species are well represented, at least in a latent condition, in the germ plasm of all specimens of the species.

The *Nemophila,* a common wild plant in California, has flowers that are generally clear, pure, sky-blue, but this varies in different localities through all shades to snow-white. Pink varieties are occasionally seen. Sometimes also the blue flowers are edged with white; and on occasion one sees white flowers with a blue edging, and sometimes a shade of yellow.

The coast tree lupine (*Lupinus arboreus*), another wild plant, bears spikes of brilliant yellow flowers. But these may vary from lemon yellow to sulphur yellow, brownish yellow, smoky yellow, reddish, pale blue, yellowish blue, dark blue, and pure white. Bright yellow is the typical or usual color, and white is quite rare. The other colors are not unusual.

The *Limnanthus Douglasii* is a wild swamp plant the flowers of which sometimes seem to carpet the ground. The upright, bell-shaped flowers are usually milk white. But I have received specimens from the Sierras that were yellow.

The beard-tongue, a relative of digitalis, of the species known as *Pentstemon barbatus,* has flowers that vary from scarlet to almost pure yellow and white.

The crimson *Clarkia* and the bluebell have flowers the colors of which are indicated by their respective names; but both on occasion produce blossoms that are pure white. Everyone knows that the heliotrope, the lilac, and the pansy, among cultivated flowers, are often represented by white forms—and the pansy by all known colors. The same is true of the *Whitelavia,* the typical flowers of which are also blue, and of the trailing myrtle, the characteristic blue flowers of which are sometimes modified to crimson and to white.

The gillias may show in the same patch flowers of the same species of the deepest crimson, others that are pale rosy crimson, yet others that are pink, and pure white.

These examples of variation in different flowers of the same species may be supplemented by mention of the curious flower, *Cynoglossum grande,* of the borage family, the flowers of which are blue in color until they are fertilized, then each blossom becomes deep red. Somewhat similar are the color changes of one of my new varieties of poppy, which vary in color from day to day. And this phenomenon of changing color while still retaining freshness may be linked with the observation that nearly all flowers change in color after they pass maturity, losing their brilliancy as they wither, and ultimately taking on altogether modified hues.

With these illustrative cases of the varied coloration of flowers in mind—and of course the list might be extended indefinitely—it no longer seems strange that the orange and white African daisies have the potentialities of a pink daisy in their hereditary strains. There is every reason to suppose that the two African daisies are descended from the same original form. It is probable that the existing differences in their colors are due to somewhat recent modifications.

Possibly the orange African daisy grew in the open, where it was subjected to the influence of sunlight; and the white daisy in a woodland or marsh where it was much in the shadow.

It is a general observation that shade-loving plants, like those that open their flowers in the twilight or at night, tend to produce white flowers or at most those dressed in light and pale colors; whereas the blues and oranges and reds are worn principally by flowers that grow in the open and put forth their advertisement for insects in the sunlight.

So we may reasonably suppose that the white African daisy owes its present color to the influence of natural selection, and that it had among its ancestors plants that bore colored flowers. In any event, the orange African daisy has colors of its own, without invoking the aid of ancestors, and their orange color shows that there are elements of red mixed with the yellow. These elements, sorted out through hybridization, sufficiently account for the pink progeny.

But among the hybrids of the yellow and white African daisies, in addition to the pink ones, are numbers that are yellow; and, in about equal proportion, others that are white. These white individuals closely resemble their white parent; yet, as one of their parents was the orange daisy, it is obvious that they have in their germ plasm factors for yellow pigment, even though these are not revealed.

A WHITE GLADIOLUS

Most so-called white gladioli are not really white, as a comparison with a pure white flower like the Watsonia would quickly reveal. We have now produced a variety of gladiolus that is really white. (One-third life size.)

These hybrids, notwithstanding the strain of yellow in their heredity, are as white to all outward appearance as their white parent; a fact which, taken by itself, sufficiently demonstrates that the white parent itself may have the submerged factors for pigment in its heredity.

It appears to be sufficiently established that white flowers may be white not because they altogether lack heredity factors for pigmentation, but for the paradoxical reason that they possess these factors in superabundance.

We saw in our discussion of the colors of the poppy that there is reason to believe that two dominant colors, grouped together, may neutralize or mask each other and produce no tangible character.

If we revert to an illustration used in another connection, in which we imagined that elfin architects are at work in the germinal nucleus, matching up the different hereditary factors to build a new organism, we may suppose that occasions arise when there is a superabundance of material (in the case under consideration, let us say, materials for both yellow blossoms and red blossoms), and that in such a case the architects might agree on a compromise in which neither yellow nor red pigment is used, the flower being allowed to remain white.

We saw evidence that there are such latent color factors in flowers in such a case as that of the yellow poppy that when matched with a white one produced a galaxy of crimson poppies. The case of the orange African daisy mated with a white one is a variant on the same theme.

And the illustration just cited of the different cases in which flowers of the same species have blossoms that may run the gamut of colors from scarlet through yellow to blue, or may lack color altogether, shows how common is the phenomenon of the mixture of factors for different colors in the same germ plasm.

We shall perhaps not be far wrong if we assume that every colored flower has underlying potentialities of other colors than the one represented. And there is a good evidence to suggest that yellow underlies red and is dominated by it when there is a mixture of different factors; that blue, lying toward the other end of the prismatic scale, stands rather by itself and in a way opposed to the other colors; and that white, as just suggested, may represent either the absence of factors for pigmentation or the presence of two or more conflicting pigments that neutralize each other.

In another connection we shall discuss a theory as to the way in which the various colors, as utilized by the flowers, were introduced, and the significance of their various blendings.

We shall find reason to believe that even the white flower is not, as a rule, white because it lacks the factors for color pigmentation, but because it mingles these factors in such a way that they mutually antagonize, or neutralize, or mask one another.

EXPERIMENTS WITH THE OLD RESPONSIVE DAHLIA

An Infinity of Variation Which Has Only Been Tapped

IF you have seen a Navajo blanket you are aware that the Indians of the Southwest are lovers of vivid colors—in particular of glaring reds.

It would appear that the insects of the same region have acquired similar tastes; for they have aided in the development of a good many flowers that advertise their wares with the most brilliant hues. The cactus furnishes a familiar instance.

Another example is supplied by the even more familiar dahlia, which in its native Mexican form had florets of bright red with a yellow center—supplying the basis for the modified color schemes of the dahlias now under cultivation everywhere.

The original red dahlia so attracted the eyes of the Spanish conquerors in Mexico that they sent the plant to Europe, and its reception there suggests that barbarian and insect have no monopoly of the color sense to which red appeals. For the Mexican composite flower was taken into the European gardens, and made to feel quite at home in its new habitat.

The new exotic came, as a matter of course, under the eye of the great classifier Linnæus. And he thought so highly of it that he was moved to name it in honor of his friend and pupil, Dr. Andreas Dahl. The great Swedish classifier spoke with final authority in that day, and "Dahlia" the plant became in all languages and wherever grown—except, of course, in its native habitat; and what it might be called there, if anything, did not greatly concern the civilized world.

The scientific generic name *Dahlia* seemed to serve as well as another for the popular name also. So the name of the friend of Linnæus has been perpetuated as a household word, familiar almost as the words rose or violet; but of course the great majority of people who pronounce it give no thought to its origin, and are quite unaware that they are paying tribute to a man, and commemorating a friendship.

So entirely has the origin of the word been overlooked, indeed, that the name dahlia, which should obviously be pronounced with the broad *a*, is universally pronounced with the long *a* in England and with the short *a* in America, each branch of the Anglo-Saxon race seemingly trying to get as far away as possible, in different directions, from the natural pronunciation suggested by the derivation of the name, and its spelling—if indeed the spelling of a word in our language can be said to have any particular association with pronunciation.

Early Development of the Dahlia

All that, however, is of no great importance. A dahlia by any other name or pronunciation would be equally attractive. What is important is that this flower, brought from its subtropical home, proved wonderfully adaptable to its new surroundings, and showed a responsiveness to good treatment that presently transformed its general appearance, and gave it secure place in the group of three or four most popular flowers.

There are several species of dahlia, all natives of Mexico or the regions a little farther south. But the species that is chiefly responsible for the development of the new races, or at any rate those that first gained recognition in Europe, is one that because of its tendency to vary even in a state of nature was named *Dahlia variabilis*.

This flower, which was introduced into England in the year 1789 by the Marchioness of Bute, has the general form of a very large daisy and it resembles numerous familiar wild sunflowerlike composites, except that its floral envelope is dull scarlet with a yellow center, instead of being yellow or white.

We have seen many illustrations of the effect of transplanting a plant from one region to another. The dahlia furnishes yet another example. Brought from subtropical Mexico to the relatively cold climate of England, it soon showed the effects of altered climatic conditions. The tendency to vary was accentuated, and when in due course the plant was hybridized with other species brought from the same region, the hybrids took on such modifications as presently to produce races of dahlias so utterly divergent from the parent forms as to be almost unrecognizable.

Not even a botanist would associate the wild composite with its eight flat florets of ordinary shape and appearance, with the relatively gigantic rose-shaped flower made up of an infinite number of tubular florets packed together into a solid head.

The colors of the flower have been correspondingly modified, although the original red and yellow of *variabilis,* together with the white and crimson of certain other species, form the basis of the coloration of all the cultivated varieties.

And as to size of stalk, whereas the original species rises to a height of seven or eight feet, there are dwarfed cultivated races that are only twelve to eighteen inches high.

In habit, there is a corresponding range of variation, some cultivated species requiring a large amount of moisture, whereas others thrive in a dry soil. Even the seed is of altered shape, and the time of blooming, which in the early part of the nineteenth century was said to be from September to November, has been so extended that some of the modified dwarfed forms are now in full flower in June.

In quite recent years a type of dahlia has been introduced in which the petals have a typical and characteristic long, slender, twisted, tapering form. This is known as the cactus dahlia, mostly because of the shape of its flower, and partly perhaps because of the brilliant scarlet color of some varieties.

The original flower of this type was found in Mexico about 1879, and was named *Dahlia Juarezii,* after President Juarez, "the Washington of Mexico." The precise origin of the plant is unknown, but it is believed to be a variety of the original *Dahlia variabilis.* In any event the new type has been crossed with other races, and it now appears, like the others, in practically all colors, with the single exception of clear blue, this color alone seeming to be unwelcome to flowers of the tribe, just as it is to the poppies and the gladioli, both of which tribes show a range of coloration strikingly similar to that revealed by the dahlias.

New Forms and Combinations

My own experiments with the dahlias have largely had to do with flowers of the cactus type. I have raised these by the hundred thousand, and have produced some really fine forms that have been introduced by Vaughan, Burpee, and others. The modifications introduced have been numerous, and some of them at least have constituted rather notable improvements, notwithstanding the elaborate development of this plant by many earlier workers.

In the course of these experiments I have endeavored to give a new impetus to variation and renewed vitality by hybridizing the cultivated forms with the species imported directly from Mexico. To be sure, the dahlias originally in hand are so hybridized—to say nothing of the original tendency to variation—that there is plenty of material for selection in any lot of seedlings.

Still it is well to try to gain some new combinations by the use of wild strains, and in this my expectations have been realized.

One of the faults of the dahlia, even in the best varieties, is that there is a tendency to expose the center of the flower, owing to the fact that not all of the stamens have been transformed into florets even in the most developed varieties. The result is that in a dry summer, or toward the end of the season, even good varieties may fail to show the fully rounded head that is prized by the connoisseur.

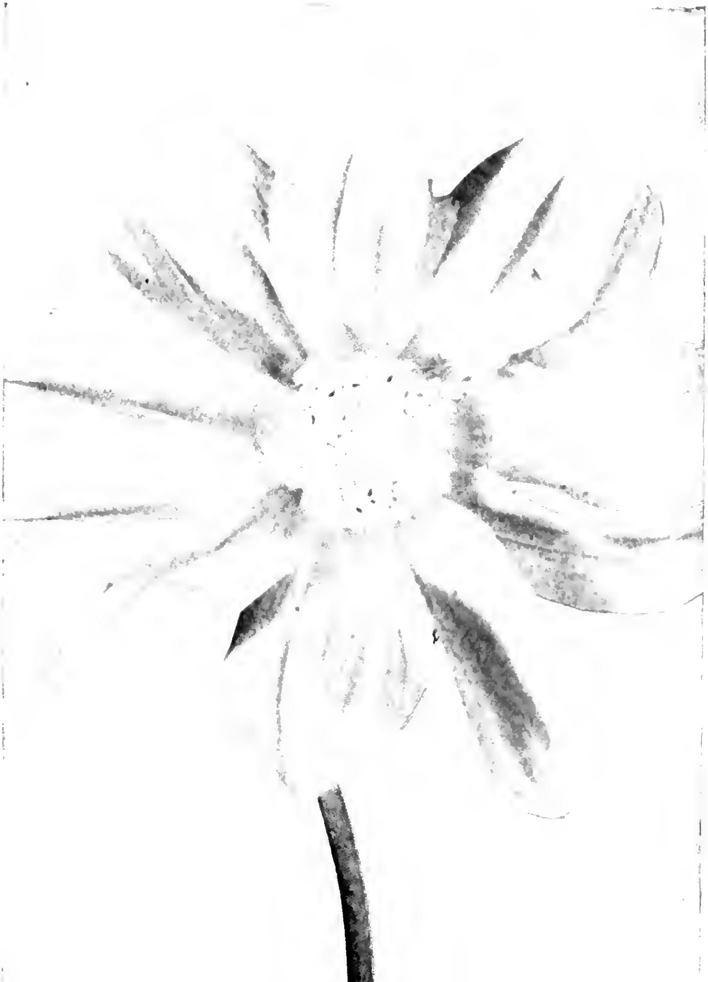
Through selection this defect was overcome, causing the heads to fill out altogether, so that they were double to the very center, even at the end of our dry California seasons. A number of varieties were thus perfected.

As the ideal sought was approximated, the flowers produced less and less seed, and the perfectly double ones produced none at all.

So the races thus developed must be propagated altogether from the tubers. This, indeed, is not an insuperable objection, inasmuch as this is a common way of propagating the dahlia. But, of course, there is always an added merit

A PRIMITIVE TYPE OF DAHLIA

The wild dahlias are sunflowerlike plants that scarcely suggest the familiar cultivated dahlias of the flower garden. It will be seen, however, that the primitive type here shown manifests a tendency to variation in form of the petals (properly ray flowers), suggesting possibilities of development.



in a garden flower that can be produced from the seed.

It is well known, however, that even the best-fixed races of dahlias are not expected to breed true from the seed. Like other specialized flowers they carry too many hereditary strains in new combinations to be expected to breed true to any single type. So while the dahlia is often raised from the seed, it is always to be expected that the seedlings will show a wide range of variation.

It is only in specimens grown from the tuber that any certain prediction can be made as to the precise characteristics of the prospective flowers.

One of my beautiful yellow double dahlias, The Golden West, has shown a curious responsiveness to the diverse conditions of soil in the gardens at Santa Rosa and at the Sebastopol Experiment Farm only seven miles distant.

At Santa Rosa the plant grows to a height of about three feet, and resembles the common types of dahlia as to its general manner of growth, though an unusually profuse bloomer.

But at Sebastopol the plant is a dwarf, not exceeding two feet in height; and as it retains its habit of profuse blooming the dwarfed form looks like a solid bouquet of cut dahlias.

Similar modifications in the size of plants, but less striking in degree, are of course common enough under differing conditions of soil, and in particular with varying moisture. But of course such variations do not affect the heredity of the plant appreciably. They have no relation with the production of dwarf and gigantic varieties in the same fraternity through hybridizing, of which we have seen examples among various races of plants.

With all its attractive qualities, the dahlia is not quite a perfect flower because it lacks fragrance.

This defect also I have sought to remedy, and as regards the mere matter of production of a fragrant dahlia, have been entirely successful. Unfortunately the new fragrant races have not hitherto combined odoriferousness with the qualities of size and form and color that enable them to compete with the best standard varieties. Still, enough has been done to show that with further selection the dahlia may be given a perfume that will greatly enhance its attractiveness.

Races of Fragrant Dahlias

In developing a race of fragrant dahlias the same rules of selection that have been repeatedly outlined were followed.

The first thing was to find an individual that revealed even the faintest pleasing aroma. In general, dahlias have either no odor, or a slightly disagreeable one. The tribe of composite flowers to which the dahlia belongs depends as a rule upon the conspicuous floral envelope to attract the pollenizing insects, and has not developed fragrance.

But it is probably true with regard to fragrance as with regard to combinations of colors that there are unrevealed hereditary factors in the germ plasm of almost every flower. The production of odoriferous oils and essences is so characteristic a phenomenon with plants in general, that we can hardly doubt that every tribe has in its ancestral strains very complex elements for the production of odoriferous compounds. Odors appear to play a very important part in plant life, not merely in the attraction of insects to facilitate cross-fertilization, but also in giving plants protection.

Otherwise it would be hard to account for the almost universal prevalence of odors of one kind or another in connection with the various tissues of the plant.

Moreover there is a far closer relationship than is commonly supposed between agreeable and disagreeable odors. Attar of roses, properly diluted, has a delicious fragrance; but the same essence in its concentrated form is positively disagreeable. Also the combination of two or more disagreeable odors sometimes produces a delightful fragrance in the hands of the perfumer.

This may give the clue to the rather puzzling fact that even among fragrant flowers there may be found occasional blossoms that have a more or less disagreeable odor. By eliminating these, the quality of the odor of a bunch of flowers is greatly bettered. Yet many persons gather flowers indiscriminately without realizing why some bouquets have more agreeable odor than others.

Making application of a knowledge of this affinity between disagreeable and agreeable odor, the search was diligently made among dahlias of various races for a long time, hoping to find one in which the disagreeable odor was supplanted by an agreeable one.

And at last the search was rewarded. I found a dahlia that had a faint but very pleasing fragrance comparable to that of magnolia blossoms.

Of course the seeds of this plant were saved, and in the following season the most careful search was made among the plants that grew from them for fragrant flowers. And, as might be expected, a certain number of these were found.

By repeated selection, always searching for the most fragrant flowers, and carefully saving their seed, a race of dahlias was developed many of which had a very agreeable perfume. Rather I should say that there were several races, for the quality of fragrance was associated sometimes with one set of characteristics of size and form and color, and sometimes with another.

Selection being made in this case for fragrance alone, as was absolutely necessary in order to intensify this evasive quality, it was necessary mostly to ignore the other qualities, and, as usual in such cases, it resulted that the new fragrant races of dahlias, while having perfume that recommended them, were somewhat lacking in the other qualities. The great popularity of the flower has led to such perfectionment of its various characteristics in recent years that the standard of competition is very high, and it would be useless to introduce a new variety that did not measure up in all regards to the existing varieties.

So up to the present time the fragrant dahlias have not been introduced, except three or four, which were purchased by Vaughan of Chicago. Further experiments in selective breeding will be necessary before the quality of fragrance is combined with satisfactory qualities of size and form and color. But there is every probability that these combinations will be effected in due course, and that races of dahlias which combine all the qualities for which the flower is now prized, with the added quality of pleasing aroma, will be available.

Wider Hybridization Attempted

We have seen that the experiments through which the original wild dahlias were transformed into georgeous double flowers of a characteristic type utilized the principle of hybridization at all stages. In my own experiments I have attempted to extend the principle, not merely to all the flowers of the genus, but also to those of allied genera.

According to the estimates of the botanist, the dahlias have fairly close relationship with plants of the genus *Bidens*. Indeed, a familiar species of the genus, known as *Bidens atrosanguinea,* a tuberous variety with dark purple flowers, is often spoken of as the black dahlia. Its tubers and foliage strongly suggest the common dahlia in miniature.

For several years I worked extensively with this so-called black dahlia, not only by way of improving the flower itself, but also in the attempt to hybridize it with the dahlia proper.

Selective breeding enlarged the flower to about twice its original size, making the rays much rounder and fuller, adding extra rays, and in changing the color of the rays from the usual dark purplish crimson to a light crimson approaching scarlet and in a few cases to a pale pink approaching white. The plant itself was also made more compact.

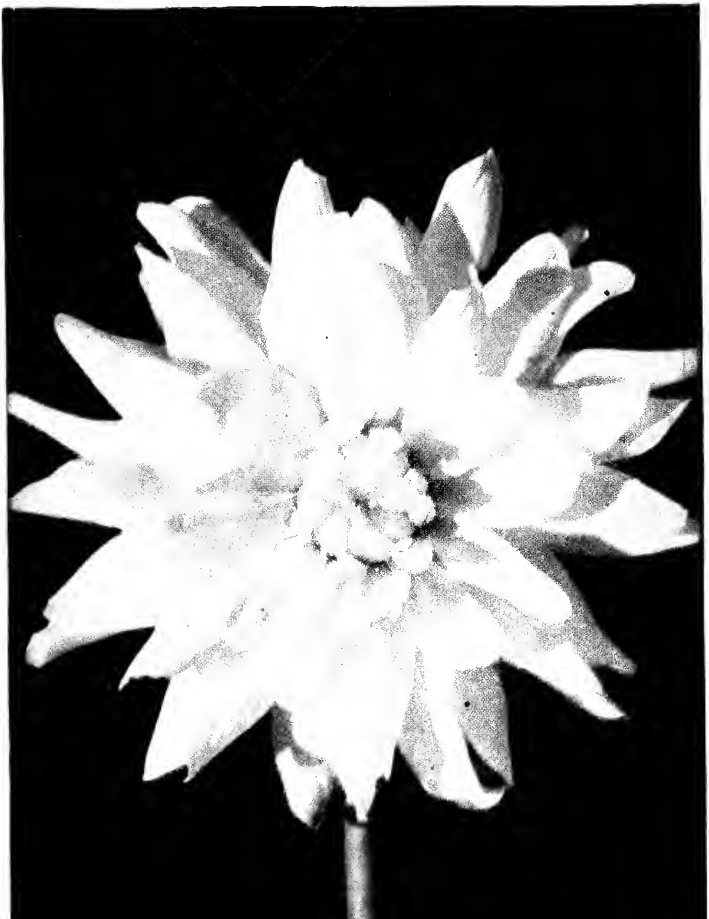
All these changes were produced by selection and reselection, working constantly toward the new colors desired, and toward increase of the size of flower, and modification of form.

The species worked with was a Mexican form. There is an aquatic California species with large, brilliant, yellow flowers, closely related to the species known in the East as "pitchforks."

For two or three generations, these flowers seemed fixed. I could see no change whatever; no tendency to break into new forms. I attempted to hybridize the two species of bidens, but did not succeed, so it was necessary to depend upon selection alone. The plants were grown in large quantities. After several years slight variations appeared; and then, as in so many

A COMMON TYPE OF THE MODERN DAHLIA

The dahlia has been grown so long and so extensively that it varies widely when grown from seed. This and a thousand other forms are likely to appear among a large colony of seedlings.



cases, the tendency to variation became somewhat accentuated.

The black dahlia and other species of bidens are well worth cultivating, and some other valuable tuberous flowering plants can be developed from them that would be welcomed by flower lovers in general.

But other engagements made it impossible to carry the experiments beyond the early stages.

And as to the matter of crossing the bidens with the dahlia, in which I had been especially interested, the result was altogether negative.

Repeated efforts failed to fertilize either species with the pollen of the other.

Notwithstanding the outward similarity of the plants, it would appear that their racial strains have diverged beyond the point of ready commingling. Still it is possible that a more extensive series of experiments might have met with better results, and further efforts along the same line are at least worth making. Could a cross be effected, we might reasonably expect some very interesting modifications in the hybrid product; notably, perhaps, an accentuated capacity for growth that would possibly give us dahlias rivaling the largest chrysanthemum in size, as they already rival it in form and flexibility of petallike florets.

Cross-Pollenizing the Dahlia

Among themselves the dahlias cross very readily, it being, indeed, difficult to keep them from crossing when they are grown near together.

Yet, as in the case of all composite flowers, the hand-pollenizing of the dahlias presents certain difficulties. The method of hand-pollenizing, with special reference to the washing off of the pollen from the pistillate flower before applying the foreign pollen, has been detailed in its application to composite flowers in general in the chapter on pollenization. It may be added that it is sometimes possible to blow the pollen away, if water for washing it off is not available. The use of a strong magnifier to inspect the receptacle and make sure that all pollen has been removed will give added certainty to your experiment.

After the pollen has been thoroughly removed by washing, apply the head of the flower that is to be used as the pollen parent, rubbing it gently against the pistillate head while it is still wet.

But to complete the experiment, it is desirable to mark the flower, and to repeat the maneuver on several successive days. This is necessary because not all the flowers in the head mature at the same time. The outer come to perfection first, and the process of maturing advances toward the center of the flower. So the first pollenizing must be done just at the right time, and successive pollenizings day by day until the entire flower has come to maturity, if all the pistils are fertilized.

It is obvious, then, that the crossing of dahlias, while it presents no real difficulties, and is tolerably sure in its results, is a somewhat tedious and laborious process where the field of operations is wide. But, as already pointed out, it is not necessary for the experimenter who is seeking merely to modify existing varieties to resort to hand-pollenizing.

The varieties that will appear among any ordinary lot of seedlings will afford him ample opportunity for selection.

On the other hand, the experimenter who wishes to develop new types of striking individuality will of course crossbreed the old ones, using species or varieties as widely separated as possible. My own experiments, as already pointed out, have involved the use of wild species from Mexico, and the influence of these wild crosses has undoubtedly been felt in the rather striking results attained in working with a race of flowers that, despite its comparatively recent advent in the horticultural garden, is already highly specialized.

That further improvements of striking character will be attained cannot be doubted by any one who takes into account the fact that the dahlia is a parvenu among the admitted aristocrats of the flower garden. It is impossible that the hereditary resources of any plant should have been exhausted within the comparatively brief period of time that has elapsed since this extraordinarily responsive and adaptable flower was first brought from the wilds.