BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 31

Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
December 30, 1913.

BEHAVIOR, UNDER CULTURAL CONDITIONS, OF SPECIES OF CACTI KNOWN AS OPUNTIA.

By David Griffiths,
Agriculturist, Office of Farm Management, Bureau of Plant Industry.

INTRODUCTION.

The investigations upon which the observations recorded in this paper are based are being conducted in three principal localities—Brownsville and San Antonio, Tex., and Chico, Cal. At each place between 600 and 1,500 varieties of prickly pear and cane cacti have been planted and grown well toward maturity or have failed to grow. With such an array of material, secured from all the prickly-pear regions of the world and representing especially that large stretch of territory between Calgary, Canada, and Oaxaca, Mexico, there is naturally a large quantity of data on various phases of the subject accumulating very rapidly.

In this paper are detailed a few of the salient features of conspicuous behavior. In the main, the points discussed here have a bearing upon some of the economic aspects of this group of plants.

While it is neither necessary nor desirable to enter into details at the present time regarding the conduct of the work, that being reserved for a future publication, a few words of explanation are desirable. At Chico, where the main collection is now handled, work is carried on both in the field and under sash shelters; at San Antonio in the field and under canvas shelters, and at Brownsville in the field entirely, thus far.

SPINE VARIATION.

To treat the subject of spine variation adequately would require a book of no small magnitude, but only a few phases of the subject will be attempted at present.

In the economic handling of the prickly pear as a farm crop in southern Texas great differences have been found in the ease with which spines are burned from different species, and the differences are to a considerable extent matters of geographical position. Native

species from the immediate vicinity of Brownsville have been employed in our economic plantings, because it was early recognized that these were the best adapted to the conditions and would make the largest tonnage of any that could be grown.

All species of this region are exceedingly spiny. They are even more spiny than those of the San Antonio region; moreover, the spines remain green for a longer period and are consequently much more difficult to singe properly preparatory to being fed. This is a serious economic consideration and one which is difficult to prevent. Under the humid conditions of the coastal region the tendency is for the spines (fig. 1, *a*) and the spicules (fig. 1, *b*) of all species to become dry much more slowly than in the more arid atmosphere of the regions farther inland.

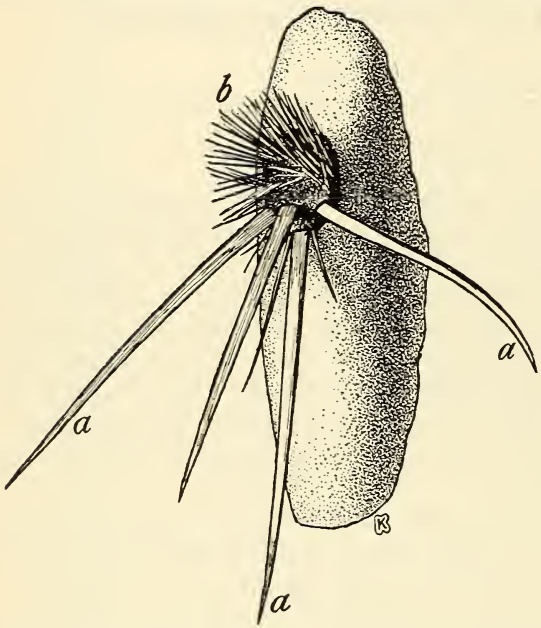

FIG. 1.—A pulvinus, or cushion of spines (*a*) and spicules (*b*), from the edge of a joint of *Opuntia lindheimeri* from the San Antonio region of Texas.

In the cultivation of this crop it is therefore necessary for one to choose between the spineless forms not needing singeing and the much more productive spiny native varieties, which are not only difficult but often impossible to singe properly. It may be possible in time to breed varieties better adapted than the native ones, but the development of such forms from the spiny native prickly pears of the delta of the Rio Grande is an almost hopeless task, the variation in the number of spines produced being so trifling as to scarcely warrant selection, while they do not appear to hybridize readily with the spineless forms.

In June, 1905, the Office of Foreign Seed and Plant Introduction of this Bureau received from Dr. G. Borg, San Giovanni, Island of Malta, a few cuttings of a large spineless species, to which was assigned S. P. I. No. 14807. The plant passes in both this country and the Mediterranean region as spineless. About half a dozen cuttings of this importation were planted and grew for two and

a half years at the plant introduction field station at Chico, Cal. They were then cut up into individual joints and reestablished in nursery form in a plantation as extensive as the stock thus produced would permit. It was noticed that one of the original plants had on one of its joints three or four spines in one or two pulvini on one side. No heed was paid to this, however, and this joint was lost sight of in the planting, which was made in nursery form. In other particulars this did not differ from the other plants.

This prickly pear belongs to what commonly passes for *Opuntia ficus indica* and is nearly spineless. Frequently short spines are produced, but they are very few in number; there is but one in an areole, and they are usually only 2 to 5 or 6 millimeters in length. It is on the whole an average of the spineless forms. When the first planting of this stock was grown, one plant which was normally vigorous showed a few rather long spines, as stated above, similar in character to the shorter ones more commonly produced, but much longer and stouter.

The establishment of the nursery plantation took place in April, 1908. The following spring all of the spineless forms (especially S. P. I. No. 14807) were cut back to the original cutting for stock. At this time it was noticed that one side of one plant of this number was very spiny and the other side as spineless as the remainder of the importation. With the rest, this plant was cut close, but the spiny cuttings were rejected. In the spring of 1910 the new growth was again in part spiny, and it was again cut back, but one joint was left attached to the original one. At that time neither joint left on the plant showed any spines.

In the spring of 1911 it was found that the previous season's growth had come mainly from the upper cutting, which grew in the season of 1909. From the original cutting two joints had sprung, one from each side. All new growth on one side of the plant, whether from the original cutting or from the younger joint, was practically spineless (Pl. I, fig. 1), while the other side was exceedingly spiny (Pl. I, fig. 2), the latter resembling the more common forms of some of the mission pears grown in all of the collections in southern California and bearing two to four white spines two-thirds of an inch to 1½ inches long. The whole plant is shown in Plate II, fig. 1.

The appearance of the plant in the spring of 1911 was so striking that it was pruned back but very little, simply enough to shape it up. Several of both spiny and spineless joints were planted, but owing to the condition of the ground when the planting was done all made a very poor growth. However, the small amount of growth that was made came true to the characters of the individual cuttings planted. In the spring of 1912 the previous season's growth was again spiny

on one side of the plant and spineless on the other, the contrast producing a very striking appearance.

This habit of reversion or bud variation, whichever it may be considered, is a very important characteristic, and, while more striking in the above variety than any other which has been cultivated in these investigations, appears to be not at all uncommon. A plant of another spineless variety on hand now bears promise to be just as conspicuous a few years hence as this one. It started to vary in the same direction last year.

All this relates, however, to the development of characters economically undesirable. It is well known that lack of spines is also a character which can be maintained by vegetative propagation, but being usually of slight variation is not as striking as the case mentioned of variation in an opposite direction. This phenomenon is an important one, for it furnishes a possible suggestion regarding the origin of the spineless varieties.

Both of these variations appear to the writer to point to the origin of the spineless species of the so-called *ficus-indica* group from the spiny ones, the spineless forms being the result of a long series of selection, both upon this continent and in the Mediterranean region, subsequent to their introduction there. The striking variation of certain spineless forms to a spiny condition is looked upon as a reversion to an original type.

In both of the striking examples of reversion referred to, the development of spines is associated with a bilateralism in the joint. In both cases one or two pulvini on one side of a spineless joint developed several large spines. A new joint on the same side and from a neighboring pulvinus was totally spiny. While this example of reversion and the common cases of variation to a less spiny condition in this group are marked and can be reproduced vegetatively, many species handled during the past six or seven years, considered to be very promising agriculturally if their spines were eliminated, have not proved sufficiently variable in spine characters to warrant any great promise in handling them. Doubtless the best species for southern Texas conditions is *Opuntia lindheimeri* and related and associated species, but *O. lindheimeri* is not a variable species. In all the seedlings grown and the vegetative propagations made in the past several years no individual plants have been seen which showed any tendency toward spinelessness. On the other hand, there are other species (Pls. II, fig. 2, and III, fig. 1) in southern Texas which are variable, and some forms of them are nearly, if not quite, spineless, although they always have spicules to a greater or less degree. All of these native variable varieties known to us are rather slow of growth as compared with the more spiny species. Being hardy to 10° F., or possibly, in rare cases, to

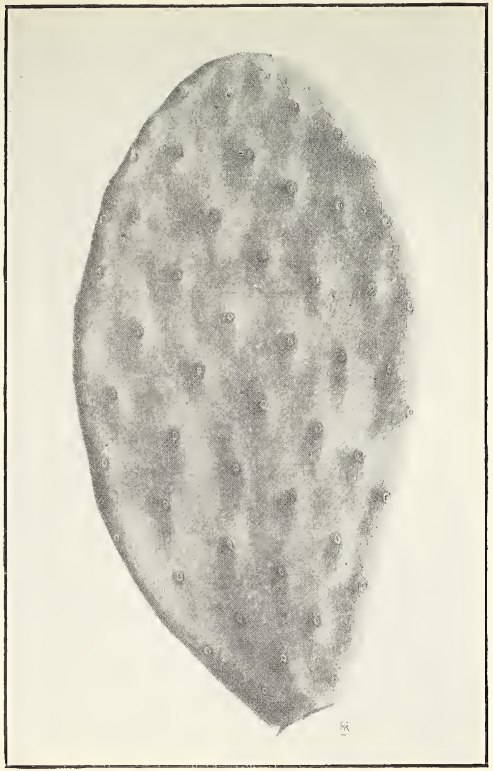

FIG. 1.—A SPINELESS JOINT FROM THE OPUNTIA SHOWN IN PLATE II, FIGURE 1.

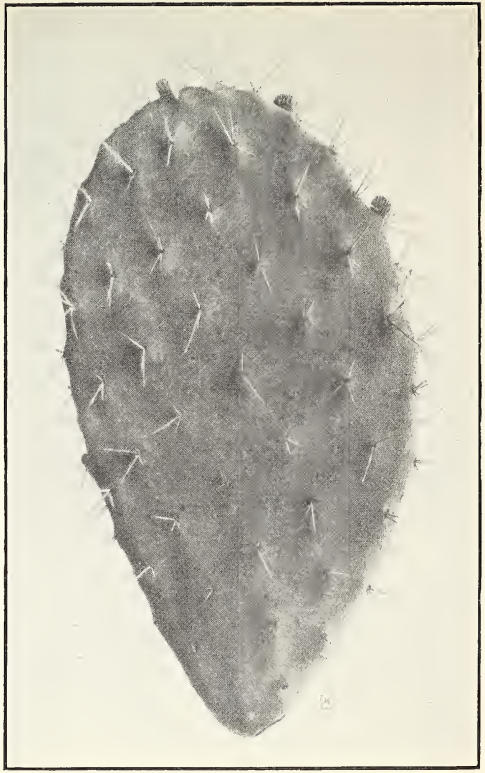

FIG. 2.—A SPINY JOINT FROM THE OPUNTIA SHOWN IN PLATE II, FIGURE 1.

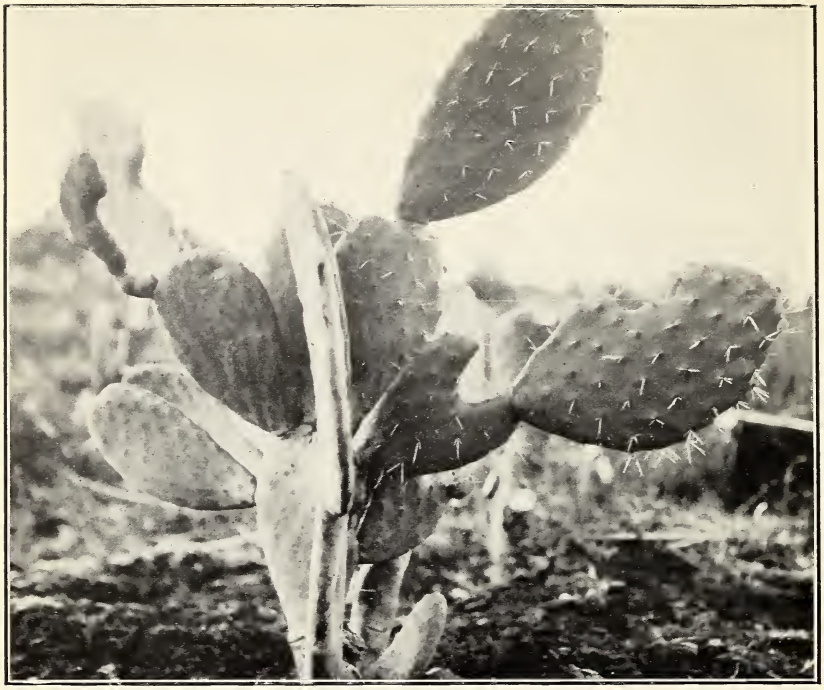

FIG. 1.—AN OPUNTIA (S. P. I. NO. 14807) WHICH IS SPINY ON ONE SIDE AND SPINELESS ON THE OTHER. COMPARE PLATE I.

FIG. 2.—A PRACTICALLY SPINELESS SPECIES OF OPUNTIA (O. SUBARMATA), NATIVE OF THE DEVILS RIVER REGION OF TEXAS, AS GROWN AT SAN ANTONIO.

SPINY AND ALMOST SPINELESS SPECIES OF OPUNTIA.

zero temperatures, they are more promising for breeding purposes than *O. lindheimeri* itself.

On the coast of California from Santa Barbara south and extending into Lower California occurs a species which has usually passed for *Opuntia occidentalis*. It differs very decidedly, however, from this species in many particulars. Its joints are oval to lenticular and pointed at either end. It is, in general, a very spiny species, but frequently spineless or nearly spineless joints are produced. Mrs. Brandegee has called attention to this condition in a general way on one or two occasions. The attention of the writer was first called to it also at San Diego, Cal., a number of years ago, in a plant which was studied on two different visits two years apart. From this plant spineless joints were set at San Antonio, Tex., but the species proved to be not perfectly hardy out of doors. The plants, however, are seldom killed outright. Some selections have been made from this original collection made in 1905. On three occasions spineless cuttings have been selected and set in the open ground. Spineless cuttings have also been taken from the progeny of the same cuttings and set under winter protection at San Antonio and in the open ground at Brownsville, Tex. They have also been established recently from the latter situation at Chico, Cal.

Invariably in all of these experiments spiny joints have grown from the spineless ones, but frequently a spineless joint is produced and in about the same proportion as in the original plant. The selections made appear to have no effect upon this character.

The character and the degree of spinelessness are peculiarly interesting in this species. The common areoles, or cushions of spines (fig. 1, p. 2), are of good size, measuring one-fourth of an inch in diameter, and have spines averaging one-half to 1 inch in length and from three to five in number. They are stout and formidable. In the spineless joints the areole is very much contracted and a little sunken, a condition which is easily recognizable in the young state when the joint is only half grown. As a matter of fact, completely spineless joints are somewhat rare. They are sometimes found, however, but more commonly there are one to a few areoles toward the end of the joint which have the normal number of spines and spicules, while the remainder may be nearly or quite free of both. At other times an equatorial section or an upper or lower half may be spineless or have spines decidedly reduced, while the remainder is normally spiny.

At San Antonio, Tex., the species grows very rapidly, usually making branches three joints in length from cuttings set in the spring. Usually there will be produced one cutting to a limb entirely or partially spineless. It is therefore possible to make selection from vegetative parts each season. At Brownsville the species does not grow

so readily, probably on account of rather poor drainage where it was planted, but there is no apparent difference in the spineless areas produced. This is a rare and peculiar instance of spinelessness which has not, as in other cases, yielded to the process of selection.

On the central highland of Mexico there occurs a cylindrical-jointed low form known to the botanist as *Opuntia tunicata*. This interesting species is of no economic importance except that it is a nuisance wherever it grows, breaking off reproductive joints almost without provocation and thereby rapidly spreading wherever stock is pastured. This species, imported by the writer from the region of San Luis Potosi (Pl. IV, fig. 1), and another specimen furnished by Mr. Alwin Berger from the collection of Sir Thomas Hanbury at La Mortola, Italy, have behaved in the same way. The La Mortola specimen has been under observation longer, however. It was received in May, 1908, and planted at San Antonio and Brownsville, Tex.

The plant at Brownsville has been under observation for practically five growing seasons. It was established from a very long cutting, fully a foot in length and characteristically spiny. This grew readily, but instead of giving rise to other joints of its kind, a very large number of small, subglobular, short, delicately spined joints were produced. (Pl. IV, fig. 2.) These were almost and often quite without sheaths on their spines. They broke off very readily, and nearly all took root in the well-cultivated ground, soon establishing a patch a foot or more in diameter. The original cutting, however, retained many of these small joints, which have become firmly established, growing to a total height of not over 4 inches in five years. Throughout the first four growing seasons no growth excepting these subglobose joints was made. None of the spines which give character to the plant were in evidence at all. During the fifth year, however, the joints have become a little larger, extending to 2 or 3 inches in length and developing a few much longer spines with silvery white sheaths at their distal ends. These spines are by no means as long as normal for the species but are still quite characteristic.

In the spring of 1912 some of these small subglobose joints were transferred to Chico, Cal., and have maintained the dwarfed condition the first summer.

This character of growth is not particularly remarkable, except for the long period of five years before the plant begins to assume its adult form. In its natural habitat the reproductive joints are common to both this and other related species, but the normal condition of the plant is assumed in a much shorter space of time.

Such behavior is particularly important, in that it leads to an uncertainty regarding the identity of different forms and has in

FIG. 1.—A NEARLY SPINELESS SPECIES OF OPUNTIA (O. CACANAPA), NATIVE OF THE LAREDO REGION OF TEXAS, AS GROWN AT SAN ANTONIO.

FIG. 2.—AN ARIZONA DESERT SPECIES OF OPUNTIA (O. DISCATA) UNDER CULTIVATION AT SAN ANTONIO, SHOWING ITS CHANGED HABIT UNDER CHANGED CONDITIONS.

The large size of the joints and the reclining nature of the main limbs are conspicuous modifications due to changed conditions.

OPUNTIA CACANAPA AND OPUNTIA DISCATA.

FIG. 1.—A PLANT IN ITS NATIVE HABITAT UPON THE HIGHLAND OF MEXICO.

FIG. 2.—A 5-YEAR-OLD PLANT UNDER CULTIVATION AT BROWNSVILLE, TEX., LACKING THE CHARACTERISTIC SPINES SO CONSPICUOUS IN FIGURE 1.

OPUNTIA TUNICATA.

the past, it is believed, even led to the establishment of botanical species upon such rudimentary conditions.

ADAPTABILITY TO CONDITIONS.

In a general way only can one classify these species with reference to their adaptability to varying conditions, and the subject can only be treated very briefly here. It would be necessary to list 300 or 400 species and tabulate the results obtained with them in our trials before anything comprehensive could be deduced. This will be possible later, but a few observations of a general nature are desirable here.

The Arizona and New Mexico species in general make a fairly normal growth at Chico, Cal., in spite of much greater fertility and heavy winter precipitation. The color is a little modified in plant body and spines, probably due to the long, dry summer. The growth otherwise is quite normal.

At San Antonio, Tex., these desert species put on a greatly increased vegetative growth and produce fruit in moderate quantity. Many species [1] have joints very much increased in size, comparable with the "robusta" group at Brownsville, described below. The joints of these species are often fully twice as large at San Antonio under cultivation as they are normally in their natural homes, and many of them become less erect in habit. (Pl. III, fig. 2.) Of course, we are discussing plants under cultivated conditions. This doubtless accounts for some of the difference, but it is certain that the added fertility and moisture influence much more. Under the still greater humidity and fertility of the Brownsville region it is scarcely possible to grow these plants at all. They may start to grow, but become exceedingly turgid, break down, and rot. Even the cylindrical forms [2] which grow so rampant at San Antonio make usually only a slow, weak development, while the closely related species [3] which also grow normally under hard conditions do very well. However, much depends on the season, it being much more difficult to handle the desert forms at Brownsville in wet than in dry years.

A matter which has surprised the writer not a little is the behavior of the species of the Laredo (Tex.) district. This region is not far removed from either San Antonio or Brownsville, it is true, but the conditions are very different. The rainfall is less and even more uncertain, and the fertility of the soil in the particular localities from which the plants were secured is much less than at either San Antonio or Brownsville. In spite of this, many species [4] of

[1] *Opuntia discata*, *O. canada*, *O. toumeyi*, and others.

[2] *Opuntia versicolor* and *O. spinosior*.

[3] *Opuntia imbricata*, *O. prolifera*, *O. cardenche*, and *O. pallida*.

[4] *Opuntia cacanapa*, *O. tricolor*, forms of *O. leptocaulis*, and *O. vexans*.

this region make a very rapid development when transferred to either San Antonio or Brownsville, Tex., and do equally well, but are not so rapid in growth, at Chico, Cal. They make even better vegetative growth at Brownsville than at either of the other places.

Another region which has furnished species for the investigations of the Bureau of Plant Industry produced equally surprising results. As a general thing species from the immediate coast of California have not proved hardy at San Antonio, but grow very well when they get slight winter protection. The inland species of California, on the contrary, from the Pomona, Redlands, and Banning regions, are hardy at San Antonio and grow very rapidly, producing much larger joints and a generally more vigorous growth. The western species (*Opuntia occidentalis*) is especially worthy of mention in this connection. These inland species do very poorly at Brownsville. They live, but the moisture supply is too great and they, in common parlance, "get too fat" and finally break down of their own weight. The large "mansa" forms so extensively grown in both wild and cultivated conditions upon the central highland of Mexico are generally hardy at two of the stations, Chico and Brownsville, but are not hardy at San Antonio. At both Chico and Brownsville, however, many of them are injured in severe seasons. All species of Opuntia from the central highland of Mexico as far south as to include the Federal District, are perfectly or nearly hardy at these two stations. Although many species from much farther south thrive well, they are usually not hardy, while species from as far south as the region of Torreon are hardy at San Antonio. Several species[1] from the southern part of the State of Puebla and even far into Oaxaca appear to be hardy at Chico, but the test with them has not been of very long duration. The most tender varieties are those of the Guadalajara and Guerrero region and the genus Nopalea in general, none of which are able to thrive without winter protection at any of the stations. They, however, thrive without heat under glass shelters at Chico.

The northern, low, hardy forms do not thrive at any of the stations and less so in winter than in summer, strange as it may seem. They act in much the same way as the species from the drier regions. They seem to become gorged with water and start to rot at the least provocation. On the other hand, when kept dry during the winter rainy season, they do very well at Chico. At San Antonio and Brownsville they have failed to grow.

In general, it can be said that southern Texas is adapted to the vegetative development of these plants, while the Chico region of California is adapted especially to the development of fruit. It is

[1] *Opuntia pilifera* and *O. hyptiacantha*.

a very noticeable feature of our work that even species native to southern Texas make a smaller vegetative and a larger fruit production when transferred to Chico; indeed, some species are decidedly unsatisfactory in vegetative growth at the latter place. Some forms from the Santa Rita Mountains of Arizona make less growth at Chico than they do upon the deserts. During the past year plants of two of them [1] made no vegetative growth, but they produced an exceedingly heavy crop of fruit.

EXCESSIVE DEVELOPMENT OF SPICULES.

Just how environment acts to produce changes in plants or plant structure is not possible to say. In the case of species of Opuntia, as in those of other plants, all that can be done is to report the facts, with little hope of explaining them. Attention has been called in another place to the increased spine growth in keeping with generally increased vigor under cultivation. On the contrary, a dwarfing of the plants by external unfavorable conditions often, but not always, produces an increased development of spicules. Possibly the most striking concrete example which has been studied is in the so-called Indian-fig group of spineless forms. Practically all of these species, when grown in close proximity to the coast in California, produce more spicules than when grown in the more favorable atmosphere of the interior valleys. Such hard conditions as those in the vicinity of Indio, Cal., even when the plants are well irrigated, tend also to decidedly increase the spicular growth.

On the other hand, 20 miles from the Gulf coast at Brownsville this group thrives well with no apparent increase in the production of its armature. But such species as *Opuntia gorda* are not at all adapted and the spicules become much more prominent at Brownsville.

In short, excessive development of spicules appears to be a direct reaction from conditions unfavorable to vegetative growth. Such conditions may be one or more of many. The dwarfing influence of the seacoast is one; excessive heat, drought, alkalinity in the soils, and possibly high winds may also be contributing factors. It is a matter of common observation that in the same species plants stunted by being robbed of their food and moisture by weeds and lack of tilth bear proportionately more spicules than others in close proximity but under more favorable conditions. This has been especially noticed in low-growing species.[2]

[1] *Opuntia gilvesceus* and *O. rufida.*

[2] *Opuntia leptocarpa* and *O. vulgaris.*

LOCALITY VARIATIONS.

A careful comparison of a large number of species in the different localities in which the experiments of the Bureau of Plant Industry have been conducted would be exceedingly interesting and instructive. However, only the salient features can be touched upon here. One or two striking cases of behavior are detailed and an attempt made to state the generalities of groups rather than the behavior of individuals. But it must be remembered that groupings in such genera as Opuntia must revolve about certain species more or less closely related until a more definite, logical classification has been adopted.

The three main localities in which these species of Opuntia have been grown during the past six years differ very widely in their meteorological and soil conditions. The behavior of these plants, which as a group are adapted to live and thrive for long periods without rain, has in many cases been very striking. The plants behave in certain roughly defined groups, not always but sometimes in groups of such natural affinities as would be considered by the botanist, but more often in what might be called geographical groups. These are in some instances more or less natural as well.

At Chico, Cal., the "tapona" group[1] of Mexican highland species under cultivation behave vegetatively in quite a normal way, although one species, as discussed elsewhere, is very abnormal in its fruiting habits. Here the seasonal rainfall is propitious although reversed, the moisture occurring in the winter instead of in the summer growing season. On the whole, however, the conditions are quite comparable when the element of cultivation is introduced to prolong the season of available moisture into the otherwise longer dry summer. The plants are more tender, owing to the superabundance of winter moisture when they normally should be dry and to the rather low temperatures of the region. The plants, however, are no more gorged with water in the spring at Chico than they often are in the summer in their natural heath. This applies to other groups as well. In point of size and color they do not differ materially from their original form except that under the stimulus of clean cultivation they grow more rapidly.

At Brownsville, Tex., this group is perfectly hardy, very poor in fruit production, and abnormally large of joint. It is common for some of the spiny forms to have joints 18 inches to 2 feet in diameter at 2 years of age. The number of joints produced is no more than normal. Among the spineless members of the group the joints produced at Brownsville, of course, are smaller, but much larger than is normal for the same varieties in Mexico. The thickness of the

[1] *Opuntia robusta* and its allies.

joints is another striking feature of the conditions at Brownsville. While the tissues are no more turgid here at any time than they are commonly at home, still under our conditions of heavy humidity and cultivation they are almost always turgid to their maximum capacity. This condition presupposes uncertainty of development, liability to break down on account of excessive weight, predisposition to rot, and consequent easy access to bacteria and fungi rendered conspicuous by exudations of large quantities of mucilage, which accumulates in large, warty excrescences. In no case at Brownsville have any fruits been produced by this group of plants, and flowers in but one case, and then very sparingly. At San Antonio, Tex., no member of this group will withstand the cold for any length of time. A few plants which have been protected behave much as they do at Brownsville, except that the joints do not reach such size.

The remarks made regarding the above group at Brownsville are generally true of a large proportion of 300 or 400 numbers of the flat-jointed forms grown here. The spineless species of the so-called *ficus-indica* group, 20 or more varieties having been grown, are very heavy in their vegetative reproduction; the joints become exceedingly large, the tissues gorged with water, and the branches too heavy to bear their own weight in many varieties, consequently becoming more easily broken than when normal and difficult to cultivate.

In some instances the heavy water content of the soil has rendered it difficult to start the plants. In June, 1911, some 400 miscellaneous varieties were reestablished in a new planting on high resaca-bank silt loam soil. The cuttings were set various ways, both shallow and deep, but all by hand. The spineless group and introduced forms generally rotted very badly and continued to rot for a year afterwards. The seasons, however, were very wet, and comparatively heavy rainfalls occurred throughout the period. The land had been thoroughly cultivated since the early winter of 1910 to kill Bermuda grass and consequently held its moisture well. The soil, of course, was naturally very fertile and had been in grass for years, formerly being a portion of the old parade ground at Fort Brown. In this instance it is believed that the ill effect was due primarily to the excessive humidity of the season, for in previous years of lighter rainfall no difficulties of this kind had been encountered, and even in the driest years plants in this situation have not suffered from lack of water.

Under the Chico conditions vegetative growth is much less rapid, the plants grow more upright, and are in the aggregate less turgid and less likely to break down of their own weight, except in winter, from the effect of cold weather, when, as is often the case, the poorly supported limbs are very likely to break off.

At San Antonio the group is not hardy, but a few protected plants are about midway in their behavior between those at Chico and at Brownsville. A couple of plants 5 years of age are 11 feet high, with no sign of blossoming yet. The vegetative growth here is heavy during the summer, but always interrupted by the severe cold of winter, the plants usually being killed outright, but sometimes only to the ground.

The effect of excessive moisture on a few species is very striking. It is a common experience to find fruits ruptured by excessive turgidity at maturity, and at times stems are found in the same condition. Under excessive moisture, or an abundance of the same, joints are always turgid. In rare instances where excessive pruning has been practiced the vascular system of the joints is actually so modified as to change it from the normally flat form into a lenticular outline, the same becoming twice its normal thickness and the tissues tremendously distended. Such a phenomenon has been observed under the conditions mentioned in *Opuntia pachona*, *O. decumbens*, and an unnamed species from Aguascalientes, Mexico, grown at Brownsville. This phenomenon, however, is rare, and probably is a forerunner of a pathological condition.

One group of cylindrical-jointed species[1] are fragile jointed naturally, and all produce some small few-spined joints in their natural state, but this character is very much accentuated under the Brownsville conditions. In spite of the favorable conditions and the rapidity of growth, it takes them longer to reach the normal adult form here than in their natural habitat. None of these species, however, grow perfectly at any of our stations.

EFFECT OF HOUSING.

Succinctly stated, the housing of these plants under glass, with either little or no heat or with a temperature kept at a point not lower than 40° F. by the use of artificial heat, tends to stimulate vegetative growth at the expense of fruit production. This, of course, in a general way would be expected.

In order to fruit out a number of Mexican species of doubtful frost resistance two years ago, duplicate plantings were made at Chico under glass and in the regular field plantation. Fortunately none of these species, of which there were nearly 100, failed to live through the winter of 1911–12 on account of cold. They were all seedlings set in the spring of 1911 from the nursery row, being then one and one-half years from seed. The third year about 20 of this lot fruited to some extent in the field. The plants in the house made at least three times the growth, but none of them fruited. The difference is very

[1] *Opuntia tunicata*, *O. pallida*, *O. fulgida*, and *O. mamillata*.

striking between the two sets. Of course, those in the house are a little drawn below, but are more normal after they reach a height of 2 to 3 feet, being then above the influence of the solid sides of the greenhouse.

It is common for the various forms to make fruit to a greater or less degree the third year from cuttings. From seed, the fruit is less abundantly, when at all, produced at this age. This is true of the spineless group and the vast majority of the large spiny species of the Mexican highlands, as well as the common forms of southern Texas, when grown at either San Antonio or Chico. However, only plants of the last of these categories grow at San Antonio without protection. For the past five years, however, we have had 100 or more tender species of miscellaneous origin at San Antonio under partial protection, simply enough to carry them through the winter without freezing. They are planted under a framework over which canvas is stretched whenever the predictions point to subfreezing weather. Kerosene stoves are used to keep the temperature above the freezing point. Under this slight protection it is remarkable how few varieties have fruited. Of species from the highland of Mexico which have fruited the third and fourth year from seed at Chico, none whatever have produced fruit the sixth year here. Some species [1] fruited very sparingly, but not until the fourth year.

Plants of a spineless species [2] and one of the other large spineless forms, after having been transferred from the field to the house as plants 3 feet high and 2 years or more of age, have produced only three blossoms after five years in the house, although they have grown to a height of 10 or 12 feet. On the other hand, all but one of the peireskias fruit abundantly under the same conditions. Attention should be called to the fact that at San Antonio the housing means little more than keeping up the temperature, for the house is simply a skeleton frame over which canvas is drawn for a very short period during the norther. It is then removed, the solid board sides, 4 feet high, remaining during the dormant season, and the whole thrown open during the summer from March to November.

LONGEVITY.

In the propagation of species of Opuntia it has been customary for the horticulturist and propagator to recommend amputation rather freely. The establishment of a new plant from a cutting of an older one is the recommended and usual practice in propagating the plants, and when once established it is universally recognized that it is only a question of time until a resetting will be required on

[1] *Opuntia dillenii, O. monacantha, O. schumannii, O. puberula,* and *O. delaetinia.*
[2] *Opuntia fusicaulis.*

account of the deterioration and unsightly condition which comes on after a few years. However, this condition is not found in all of the species, but it does obtain in the low, prostrate, and bushy forms with which growers have had the most experience. A very large proportion of the species are trees and grow indefinitely as such. The low forms, on the other hand, have a tendency to die out in the center and have to be reestablished by terminal cuttings; or, as is usual in nature with many species, the main limbs resting on the ground strike root and continue to extend the plant in all directions. This is especially true of the small and northern forms and implies that the plants deteriorate in such a way as to become unsightly, if, indeed, they are not often threatened with a worse fate in a few years by dying outright. This is exactly what takes place with many of the small species which are grown in conservatories. The older portions of the plants die and the younger portions, radiating outward from the old center, establish themselves by striking root and become really independent plants but very unsightly.

In some species, most notably that known to the botanist as *Opuntia parryi* and its allies from the California-Nevada Desert, wherein the joints are club shaped and bent into a semicircle, the connection with the old parent plant is not broken, at least not for a long time. The center dies to all appearance, like the other low species, but in fact only the upper portion of the joint dies and the lower portion, forming a hard, woody cord, continues to live indefinitely and connects the successive joints of the radiating arms. This gives the plant a still more ragged appearance.

Conditions apparently affect the age of certain species at least, and at times those which grow naturally for a great number of years in their natural habitat behave very differently when placed in a different locality and under different conditions. *Opuntia spinosior*, for instance, from the deserts of Arizona, is not considered a particularly short-lived species. It is very slow of growth and certainly an estimate of 15 to 20 years would be modest for its lease of life. It grows rather freely from cuttings at San Antonio and is exceedingly rapid in its development, commonly attaining a height of 4 feet in two years, blossoming sparingly the second year and very profusely the third, but the plants are almost invariably dead by the end of the fourth season, although they may reestablish themselves from self-made cuttings. This phenomenon is a very peculiar one but appears very regularly and has now happened with six distinct plantings. The outer tissues turn brown and this finally extends over the entire plant, beginning at the ground. This behavior is universal with this species in this situation and is confined to it, no other species apparently being affected in exactly the same way. Our plants have been secured from Arizona, from La Mortola,

Italy, and from Berlin, and all have behaved in the same way. At Brownsville the species has not been planted until lately, but at Chico there are plants from the same sources which are 6 years old that show no signs of deterioration at present and have always been healthy.

Several of the small-jointed, low, prostrate species behave in the same way at San Antonio, and are comparatively short lived. They are universally attacked by a fungus, which may account, at least in part, for the rapid deterioration. *Opuntia allairei*, especially when placed under cultivation at San Antonio, grows with great rapidity. Cuttings set in the spring blossom from the current year's growth in the fall. The second year the growth is very vigorous also, but the third year it is not as prolific, and the fourth season the plant is invariably in bad shape, but usually reestablishes itself freely from detached and terminal cuttings which have been formed by the death of the older proximal growth. *O. allairei* is not killed outright like *O. spinosior*, but its condition becomes very poor and the root may die. There is always more or less fungous injury associated with this phenomenon, but it does not seem possible that it is accountable for all such damage. A number of other species become weakened also after the third year, due more evidently to the attacks of fungi. *O. macrorhiza*, *O. xanthoglochia*, *O. leptocarpa*, and *O. fuscoatra* are in especially poor condition after the third year at San Antonio. Only the last named has been grown at Brownsville for four years, but it has not suffered at all yet, though its growth is much less rapid. At Chico none of them appear to suffer in this manner, but they grow much less rapidly than in either of the other situations.

At Chico there are no signs of breaking down in any of the plants. At San Antonio, besides those noted above, there are a number of other species[1] which have many joints dropping off in the center, indicating a breaking down of the plant, which will probably progress very rapidly during the next two years. Unfortunately, the varieties grown at Brownsville and their handling have not been such as to give positive information along this line.

At San Antonio *Opuntia neoarbuscula* has a behavior much like *O. spinosior*, but not so pronounced. It grows very rapidly when once established and may at times even blossom the first year from cuttings. It invariably is very vigorous and healthy for two years, shows signs of deterioration the third, and by the fourth year is in bad shape. It continues to live at least six or seven years, but its condition is very poor, usually about three-fourths of the branches being dead, the old trunk dry and scaly, and the inner tissues largely unhealthy. Cuttings can always be established, even from

[1] *Opuntia texana* and *O. gilvoalba*.

these partly diseased branches, which will grow vigorously for about two years, then deteriorate, as stated above, repeating the history of the parent plant. From all appearances this species is in nature long lived. No one knows just how old the plants become, but certainly they do not die from age in nature in less than 15 years, and in no case have phenomena been observed similar to those which occur in the ones under cultivation.

Just what these phenomena mean or why they occur in the particular way in which they do is a matter well worthy of investigation. Although not occurring at present in any of the strictly economic species, the behavior is still an important one to study, for if it be a communicable disease it immediately becomes very important. The evidence, however, seems to be rather against this view for several reasons. In the first place, the phenomena have not yet been observed except at San Antonio, and in the second place cuttings from the nearly dead plants reestablish themselves readily and grow vigorously for two years, even when set in the identical spot in which the parent plant stood. Diseases are common upon species of Opuntia in this locality, but if this be a disease it behaves very differently from any of the others. It seems to be always present on one species, from whatever source obtained, and does not appear to do any injury in any other locality.

EFFECT OF LOW TEMPERATURES.

A discussion of low temperatures has necessarily occurred under other topics; consequently, only a partial analysis of it will be made here. In previous publications of this Bureau it has been stated that a temperature of 20° F. was about the minimum that the conventional spineless species of the so-called Indian-fig group could withstand. This is a general statement of the case. No one can set a definite temperature at which they will be injured, any more than one can for other plants. So much depends upon conditions of temperature before and after the freeze that an exact statement is not possible. The various species of the genus are killed with cold at varying temperatures between the freezing point and 40° below zero for the small, extreme northern forms. Many tropical species, more especially those belonging to the genus Nopalea, will be killed at much higher temperatures than 20° F. Even these seem able to withstand lower temperatures when they are dry than when gorged with water or when the ground is wet.

The first visible effect of low temperatures on the plants is a drooping condition. The tissues weaken at the articulation especially and become flaccid and partially disorganized. When poorly supported there is a break, usually at the articulation in the flat-jointed species, and the heavy limbs drop off. The power of recovery

FIG. 1.—THE CARDENCHE SHOWN IN FIGURE 2 (LEFT-HAND PLANT) IN FEBRUARY IMMEDIATELY AFTER A FREEZE.

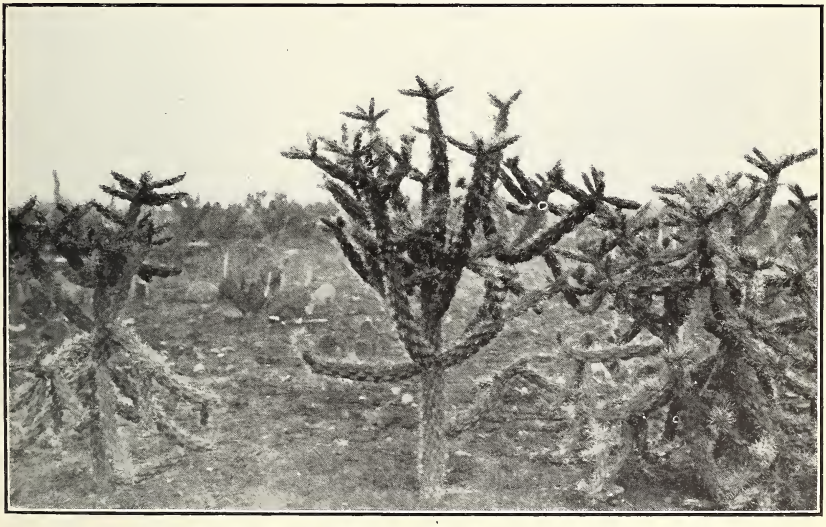

FIG. 2.—THE SAME PLANT (ON EXTREME LEFT) IN LATE APRIL, SHOWING NEARLY COMPLETE RECOVERY FROM THE EFFECTS OF THE FREEZE.

EFFECT OF FROST ON CARDENCHE (OPUNTIA IMBRICATA).

FIG. 1.—CARDENCHE (OPUNTIA IMBRICATA), ILLUSTRATING THE PERMANENT DROOPING OF THE BRANCHES BROUGHT ABOUT BY COLD WEATHER.

FIG. 2.—A SEEDLING OF OPUNTIA LEUCOTRICHA, SHOWING THE TREE FORM OF THE PLANT.

after a low temperature is remarkable in many species. Limbs which have become discolored and droop through an angle of 90° or more will often recover and regain their normal position. This has been strikingly illustrated in several instances in connection with spineless forms. In one case, where a loss of at least 50 per cent was estimated from a heavy freeze at Chico, the result was an actual loss of not over 2 per cent. Under no consideration should the plants be cut, bruised, or handled at such a time, for the results are always disastrous on account of the rapid rotting which is thus promoted.

Plate V and Plate VI, figure 1, give a graphic representation of the effect of low temperatures upon "cardenche"[1] at San Antonio. This is a cylindrical species and consequently more susceptible of graphic representation than the flat-jointed forms. Plate VIII shows the same plant before and after recovery from the effect of a spell of cold weather. It will be noticed that in one view the branches hang limp by the side of the stem; in the other they have recovered almost to their normal position. In some cases, as represented in Plate VI, figure 1, the recovery is not complete and the limbs hang down permanently, but are not injured further than this. This species grows spontaneously upon the highland of Mexico and is at about its limit of hardiness at San Antonio, where the photographs for Plate V and Plate VI, figure 1, were taken. In no case has any visible permanent injury been done, resulting in an actual loss of portions of the plant during the period of experimentation, although the condition seen here has been common. The condition shown in Plate V, figure 2, was brought about by a temperature of 18° F. in February, 1905. In the following April the plant had recovered, as shown in Plate V, figure 1, left-hand plant. The same phenomenon occurs, but in a less conspicuous way, in the flat-jointed forms.

As stated above, the effect of low temperatures is precisely the same on the spineless economic species, but they are less strongly constructed at the articulation between joints. The drooping is consequently more easily brought about, more pronounced, and more likely to result in the breaking off of large limbs. At San Antonio the spineless forms have gone down in a heap of disorganized tissue from which there is no hope of recovery. At Chico, on the contrary, the drooping, weakened condition of the nodes has occurred several times, but the recovery has been all but complete.

In the Salt River Valley of Arizona one of the hardest of the spineless forms is grown. Here it is a matter of common observation that the low temperatures of winter often trim the plants severely by the same process as that mentioned above.

---

[1] *Opuntia imbricata.*

COLORATION.

It is customary in descriptive works to place more or less dependence upon the color of flowers, and authors usually have described the color of the flowers they were dealing with quite faithfully. Unfortunately, little attention has been paid to the changes of color which take place in the flowers from hour to hour during the day. The descriptions therefore must be looked upon as depicting the condition at one particular time only. Flowers of fully one-fourth of the species change color decidedly as the day advances. On rare occasions the flowers open the second day and then the change is still more marked. Some change from light yellow to deep orange with a tinge of red, some from light yellow to pink, others from brick red to deep purple, etc. On the other hand, many species have variously colored flowers in different individuals, each changing or not, as the case may be. One of the cane cacti of southern Arizona [1] has flowers ranging from greenish yellow through chocolate to bright purple, and two others [2] have almost as great a variation.

The wealth and variety of green exhibited by these plants are scarcely excelled in any other group, and the color of any one plant is by no means constant. There is the color of the old, the young, and the middle-aged joints, the autumn and spring color, as well as the color of health, disease, and protection. The color of the young growth is often strikingly beautiful, but similar colors may often be produced by cold weather or at times by severe drought. Common forms which exhibit this characteristic more especially are some of the flat-jointed species.[3]

Species which are normally a bright or blue green color in their native habitat upon the highland of Mexico are often more yellow at the close of the hot, dry, cloudless summers of the Sacramento Valley, while, unless injured by an exceptionally cold winter, they may be even more deeply colored in the spring than they are in their native heath. On the other hand, the members of the green glaucous group [4] are, if anything, more gray than at home, while at Brownsville, under seacoast conditions but still protected from the sea, the color is much less striking.

The conditions at Chico appear to make the gray, blue-green species of the highland of Mexico more gray in autumn than they normally would be. This is probably due to the long, rainless summers. The spring color of vegetative parts is, in nearly all species whose young growth is tinted, brighter here than normal, although of the same

[1] *Opuntia versicolor.*

[2] *Opuntia spinosior* and *O. echinocarpa.*

[3] *Opuntia phaeacantha, O. chlorotica santarita,* and *O. macrocentra.*

[4] *Opuntia robusta.*

general nature. This is probably accounted for, in most cases at least, by the cold nights of April and May. It should be mentioned that the season of blossoming is a month earlier at Brownsville than at Chico. In general, all species are inclined to be a little more gray in the fall and the young growth a little more highly colored in the spring at Chico than at either of the other stations. The purplish tinge so common in species of the flat-jointed group is as unstable a character as it is in other groups of plants, in spite of the fact that in some descriptive works it is considered of fixed value. Purplish tints may be induced at will in many species. The subjection of the plants to low temperatures will often cause them to turn brilliant in color, while many assume the same aspect when the root system is injured, or from other causes if they suffer from drought.

PROLIFERATION OF FRUIT.

There are a number of species in this genus which have under normal conditions proliferous fruits, that is, new fruits rise from the old ones, which become incorporated as a permanent part of the plant, thus making pendent bunches of fruits of greater or less extent. Sometimes the fruit remains attached indefinitely but is not proliferous, as in the common white-spined cane cactus of the highland of Mexico;[1] or it may be proliferous and form large pendent bunches, as in the cholla of southern Arizona,[2] *Opuntia prolifera* of southern and Lower California, and the South American species[3] so extensively introduced into Australia. One cane cactus of southern Arizona[4] is not proliferous fruited in its native heath, but when grown under cultivation in a more humid atmosphere in California it is very commonly proliferous fruited, and this character is more especially brought out in that form of the species from the borderland between the typical form and its closest relative, the Colorado–New Mexico cane cactus.[5] It is not at all uncommon to find bunches of a dozen fruits of this form all attached in some of the California collections. The truly desert form does not appear to assume this habit as readily. At Chico and San Antonio only the desert forms have been grown, and in neither situation have they yet taken on this habit.

In some instances there appears to be some correlation between this proliferation and sterility. The fruit of the southern California cholla[6] is usually sterile. Sometimes a single seed is produced which no one, so far as known, has ever caused to germinate. The fruits of the Arizona cholla[7] apparently have normal embryos and are abundantly produced, but no one has as yet reported

[1] *Opuntia imbricata.*
[2] *Opuntia fulgida* and *O. mamillata.*
[3] *Opuntia monacantha.*
[4] *Opuntia spinosior.*
[5] *Opuntia arborescens.*
[6] *Opuntia prolifera.*
[7] *Opuntia fulgida.*

success in growing them. On the other hand, the short-spined cholla [1] of southern Arizona and the South American flat-jointed species [2] appear to grow readily.

The most interesting cases of proliferation are those caused by enforced infertility brought on by interference with the normal activities of the plant. Possibly the commonest of these is one brought on by the attacks of a small fly [3] which deposits its eggs in the very young flower buds, causing complete sterility of the fruit, which becomes strictly vegetative and gives rise commonly to normal, belated fruits of small size. These usually drop off the second season, but occasionally they become incorporated as a permanent part of the plant. A similar condition has been observed in the so-called *Opuntia puberula* of European botanists by the attacks of the black opuntia louse. This insect congregates on the tips of the young flower buds and not only prevents them from opening but renders them completely sterile and proliferous (Pl. VII, fig. 1), a second crop of normal, fertile blossoms being induced to grow out of the ones rendered infertile by the lice, unless they, too, should be attacked, when they also become sterile.

Proliferous fruits are of considerable importance upon the stock ranges of the Southwest. In the chollas of southern Arizona and southern California we have plants altogether too spiny for stock to graze, but the abundant bunches of fruits are much smoother, furnishing succulent and nutritious morsels which contribute not a little to the sustaining capacity of the ranges in times of need. The flat-jointed species of South America [2] would appear to possess the same characteristics. The chollas of the highland of Mexico,[4] although possessing very smooth fruits which remain attached to the plant indefinitely, are too acid for stock to relish. In the United States there are about half a dozen species whose fruits appear to be incorporated as a permanent part of the plant. In some other cases this permanency is brought about by purely artificial conditions, all of which indicate a closer association between the stem and the fruit in this group than is common. Were it possible to engraft this character upon some of the spineless species, their value for forage purposes would be very much increased. The fact that the character occurs in both cylindrical and flat-jointed forms indicates that this feat is not at all impossible of accomplishment.

HABITS OF THE PLANTS.

Nothing has been more clearly shown in our investigations in seed germination of species of Opuntia than the fact that vegetatively propagated plants are far from normal in general aspect. This

[1] *Opuntia mamillata.*
[2] *Opuntia monacantha.*
[3] *Asphondylia opuntiae.*
[4] *Opuntia imbricata.*

FIG. 1.—OPUNTIA PUBERULA, SHOWING PROLIFERATION IN FRUIT CAUSED BY ATTACKS OF PLANT LICE.

FIG. 2.—OPUNTIA LEUCOTRICHA, SHOWING ITS HABIT WHEN GROWN FROM CUTTINGS.

In the foreground is a small seedling of another species. The large plant only approaches the tree form, although it has been trimmed to a considerable extent.

OPUNTIA PUBERULA AND OPUNTIA LEUCOTRICHA.

FIG. 1.—THE FORM OF SEEDLING IN A MEXICAN HIGHLAND SPECIES OF PRICKLY PEAR.

FIG. 2.—THE SPINELESS AND MEXICAN HIGHLAND SPECIES OF PRICKLY PEAR WILTED BY LACK OF WATER AT CHICO, CAL.

SPINELESS AND MEXICAN SPECIES OF OPUNTIA.

applies more especially to the larger species, mainly of Mexican origin, but also to a great number of the larger forms of the southwestern United States.

When grown from cuttings the average species will produce fruit the third year, and the larger forms will continue to increase in size, generally forming a bush of more or less hemispherical outline, unless pruning is practiced, thereby shaping them artificially into trees. When grown from seed, however, all of these larger species, both spineless and spiny, are arborescent in habit, producing an erect, cylindrical trunk of greater or less dimensions and then expanding into a top, like any other tree. This point is beautifully illustrated in Plates VI, figure 2, and VII, figure 2, where are shown two plants of the Mexican durasnillo,[1] one grown from a cutting and the other from seed. Plate VIII, figure 1, shows another arborescent species about 2½ years old, from seed. The peculiarities mentioned are clearly shown in these illustrations. The point will be still more clearly appreciated if one stops to consider what a different form of plant would result if the third joint from the ground (Pl. VI, fig. 2) were to be planted. In that case, if the cutting were inserted to its middle in the ground there would result a bush, branching from its very base, with the main branches ascending and the resulting plant a hemispherical shrub; in other words, an opuntia tree grown from a joint is headed on the ground.

This is the condition of practically all plants in cultivation in conservatories and gardens, as well as in a great many of those growing naturally in their native countries, for even there the reproduction is largely vegetative, resulting in possibly the majority of cases from chance cuttings.

This has both an economic and a scientific bearing, economic in that the habit of the plants is an important consideration when these are to be grown under field culture; indeed, one serious objection to the plants is that the straggling branches get in the way of the tillage implements and are broken off, resulting in loss and rendering the fields unsightly. The best plant for cultivation is one with ascending arms forming a dense, compact head. On the other hand, the systematic botanist is leading his audience far astray when, as is too often the case, he describes the habit of the vegetatively reproduced plant, even though this may be the form commonly seen. In many cases it is next to impossible to-day, without growing seedlings, to describe accurately the form which the typical plant has—manifestly an impossible undertaking in the vast majority of instances. This has led to much of the confusion found in the literature of these plants and contributes not a little to the difficulty of

[1] *Opuntia leucotricha.*

agriculturists, especially in Australia and South Africa, in recognizing their plants from descriptions and illustrations.

MOISTURE REQUIREMENTS.

The adaptability of species to varying conditions of humidity has already been partially covered on another page, especially in so far as the effect of a large supply is concerned. The important point in this connection is the minimum moisture under which the plants will thrive. It can not be too positively urged that a minimum requirement is easily reached, or that our deserts are incapable of supporting crops of native pear—much less of the spineless introduced varieties.

At neither Brownsville, San Antonio, nor Chico do well-established plants under cultivation ever suffer from drought. At San Antonio, on the other hand, common experience teaches that the native species become badly withered during prolonged periods of drought. The same condition is occasionally seen in the vicinity of Brownsville, but less frequently. Under cultivation, however, the supply of moisture is sufficiently conserved to tide over any drought that ever occurs without any wilting of the plants.

There is a vast difference in the moisture requirements of different species. In 1907 a collection of about 100 species was growing at Chico. The plants were mostly in their second year's growth and consequently well established. Owing to a misunderstanding the plantation was not cultivated or irrigated until the month of August.

Plate VIII, figure 2, shows the effect in a very graphic manner. In the illustration are shown mainly spineless and Mexican highland species, all of which are badly wilted. All of these species thrive without the least sign of wilting when well cultivated. Scattered through the plantation shown in the figure are a number of Arizona flat and cylindrical jointed species, none of which appear to have suffered in the least from lack of attention. The conspicuous plants in the foreground are from the region of Guadalajara and are in the worst condition of any. The next to suffer were the spineless forms, and those which suffered the least or which suffered none at all were the truly desert species.[1] Since the season of 1907 all of these species, together with many others, have been grown under good cultivation. None of them have shown any indication of suffering from drought, excepting an occasional plant whose root system had received accidental injury. Even cuttings of the spineless species, if well established in early spring and well cultivated, do not suffer from drought, and they are much more likely to grow than the desert species. In-

[1] *Opuntia discata, O. canada, O. fulgida, O. spinosior, O. rufida, O. laevis, O. phaeacantha, O. macrocentra,* etc.

deed, some of the desert species seem to require more water in starting from cuttings than do the spineless ones, although when established they thrive on much less water. This is to be interpreted to mean that the desert species root much less readily and consequently are more withered before they become established than the spineless ones. As the season advances here, there is less and less moisture in the soil, giving the forms which root quickly a decided advantage over the others.

SUMMARY.

(1) Spiny plants grown near the coast of Texas mature their spines much more slowly than in drier regions. This makes them more difficult to singe.

(2) A variation in the number of spines is characteristic of certain species. In other species there is practically no variation.

(3) Many of the hardy species of southern Texas are not promising for breeding by selection, because of a lack of variation. They are very constantly spiny, and spine production is directly proportional to general plant vigor.

(4) The indications, so far as they exist, are that the spineless species have been derived from spiny forms.

(5) Conditions of growth may decidedly modify the spination and especially delay maturity of some species.

(6) In general these plants adapt themselves well to changed conditions. The spineless forms, many of the Mexican highland species, and the genus Nopalea in general thrive well with an abundant moisture supply, but the species from the drier regions are difficult to grow where the supply is constant and are much more difficult to establish under any condition.

(7) All forms thrive best when the moisture supply is low during the dormant season.

(8) Wherever tried, some species or form native to the region has proved more productive than introduced forms.

(9) Environmental conditions appear to have more effect on the production of spicules than on the production of spines. In general, factors which are unfavorable to vegetative production appear to stimulate the growth of spicules.

(10) The conditions in southern Texas appear to be decidedly favorable for the production of vegetative growth, while those in California are better adapted to fruit production in these plants.

(11) Prolonging the growing season by housing appears to increase vegetative growth at the expense of fruit production.

(12) A few species behave peculiarly at San Antonio. Their period of life appears to be very much shorter than at either of the other localities.

(13) Considering the succulence of the plants, their power of recovery from the effect of low temperatures is remarkable. Large limbs which hang limp beside the plants will often regain their normal position upon the advent of growing weather, provided they are not disturbed while the weather is cold.

(14) Color characterizations both in flowers and plant body are very deceptive, changing as the day advances in the former and changing with temperature, moisture, health, or disease in the latter.

(15) Proliferation of fruit is not necessarily a specific characteristic but may be brought on by extraneous conditions. If this habit could be induced in the economic forms their value for forage would be decidedly increased.

(16) In all of the larger species especially, the plants grown from cuttings and those grown from seed present a very different appearance; the latter are treelike and the former are headed on the ground without distinct stems.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1913