The propagation of medicinal plants*

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An understanding of the best methods of propagating medicinal plants is essential to their successful cultivation. Their cultivation or commercial production is not a new industry, in fact certain phases of it are extremely old, though poorly developed. However long some of them have been continued under cultivation, there are still many phases of their propagation which have never been investigated. Repeated crop failures in the production of henbane in England have occurred during the past thirty years, and still the most recent reports continue to mention the uncertainty of germination without any attempt at explanation.

This condition is now changing, and the last few years have seen a more general and widespread interest in the thorough investigation of a rather selected list of drug plants than was hitherto experienced. The organized efforts of the United States Department of Agriculture are conducive to the continuation of this interest. England, Germany, and Austria have not been slow in following the example of the United States, and are now advocating the national support of comprehensive drug plant investigations.

The success of these investigations must of necessity depend upon the readiness with which supplies of seeds and plants can be obtained, and the ease with which they mav then be propagated. The means of propagating medicinal plants need not differ in the main from those employed for other economic forms. Seedsmen, nurserymen, florists and gardeners all have their special and well-perfected systems of propagation for their respective classes of plants. The questions involved in these systems are not only those for increasing the number of individual plants, but also those involving the blooming and fruiting periods, harvests, markets, special crops, improvements, and breeding operations. Any

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method of propagation which does not augment these conditions is soon abandoned. Also, in the case of medicinal forms, the problems of propagation, though essential of solution, are only supplementary to other more valuable and interesting ones. The improvement of drug plants through selective breeding and hybridization, their successful cultivation upon a commercial scale, with the involved questions of practical and economic production, are more attractive, but in the end are all dependent upon successful propagation.

With medicinal plants it is many times difficult to obtain sufficient materials from which to propagate. Isolated, restricted, and many times unknown regions of production, make it almost impossible to obtain either seeds or plants. Even syndicates and sometimes government control have so monopolized these regions that they are practically inaccessible to the individual investigator. In an effort to obtain sufficient material with which to evolve certain problems upon the cultivation and improvement of the more valuable drug plants, difficulties were soon encountered in locating reliable sources of supply. Any study of the methods of propagation must therefore consist of, first, the obtaining or locating of suitable materials and, second, the various methods by which these may be successfully propagated and perpetuated. The first part of this discussion will, therefore, deal with probable sources of seeds and plants and the second with their propagation.

A thorough search has been made in an effort to locate the best and most probable sources for these materials. The results are given under the following five divisions:

I. Commercial samples and shipments of crude drugs.

II. Crude drug merchants.

III. Individuals living in or near producing regions, or others carrying on investigations with similar plants.

IV. Public and private botanical gardens, experiment stations and other institutions.

V. Commercial seedsmen and nurserymen.

A discussion of these sources together with results obtained follows in the foregoing order.

I

From commercial samples and shipments of crude drugs in which the aerial parts of the plants are used, germinable seeds are often obtainable. Many lots of drugs must be examined, however, and large numbers of questionable seeds examined and tested. In addition to furnishing material for planting, this procedure also serves as a valuable means of accurately identifying some crude drug of questionable origin. The age of seed from this source is always unknown and considerable time must be allowed for possible failures in germination. Among the forms of which seed may be obtained in this manner are American wormseed (*Chenopodium ambrosioides*), angelica (*Angelica atropurpurea*), anise (*Pimpinella Anisum*), arnica (*Arnica montana*), belladonna (*Atropa Belladonna*), broom tops (*Cytisus scoparius*), buchu (*Barosma betulina*), cannabis indica (*Cannabis sativa*), capsicum (*Capsicum fastigiatum*), caraway (*Carum Carvi*), cardamom (*Elettaria Cardamomum*), castor bean (*Ricinus communis*), celery seed (*Apium graveolens*), cevadilla (*Schoenocaulon officinale*), coca (*Erythroxylum Coca*), colchicum (*Colchicum autumnale*), colocynth (*Citrullus Colocynthis*), conium (*Conium maculatum*), coriander (*Coriandrum sativum*), fennel (*Foeniculum vulgare*), goats' rue (*Galega officinalis*), grains of paradise (*Amomum Melegueta*), henbane (*Hyoscyamus niger*), jumbul seed (*Abrus precatorius*), larkspur (*Delphinium Consolida*), Levant wormseed (*Artemisia pauciflora*), lobelia (*Lobelia inflata*), nux vomica (*Strychnos Nux-vomica*), parsley seed (*Apium Petroselinum*), passion flower (*Passiflora incarnata*), poppy heads (*Papaver somniferum*), scullcap (*Scutellaria lateriflora*), senna (Cassia *acutifolia* and C. *angustifolia*), serpentaria (*Aristolochia Serpentaria* and *A. reticulata*), staphisagria (*Delphinium Staphisagria*), stramonium (*Datura Stramonium*).

Germination tests have been made upon a number of the above forms as follows:

American wormseed. .....
Angelica. .....Fair germination.
Anise. .....
Arnica. .....Three tests. No results.
Belladonna. ..... About 50 per cent. germination.
Broom tops. .....No results.
Buchu .....5 per cent. germination.

Cannabis indica. ..... 100 per cent, germination.
Caraway. .....
Cardamom. .....Two tests. No results.
Celery seed. .....
Cevadilla. .....One test. About 25 per cent.
Coca. .....Four tests. No results.
Colchicum. .....Three tests. About 5 per cent. from one.
Colocynth. .....Most tests give from 5–10 per cent. germination.
Conium .....50 per cent. germination or over.
Coriander. .....
Fennel. .....
Goat's rue. .....One test gave 5 per cent. germination.
Grains of paradise. .....
Henbane.....Most tests give 5 per cent. germination, or more.
Larkspur. ..... 100 per cent. from most tests.
Levant wormseed..... No results from 2 tests.
Lobelia. .....
Nux vomica. ..... No results from 5 tests.
Parsley seed.....
Passion flower. .....One test gave 3 per cent. germination.
Poppy heads. .....All tests gave 100 per cent. germination.
Scullcap.....One test out of three gave about 5 per cent. germination.
Senna.....Most tests gave fair germination.
Serpentaria. .....No results from 2 tests.
Staphisagria.....One test gave 3 per cent. germination.
Stramonium.....All tests gave 50 per cent. germination, or more.

Large numbers of seeds were used in most of these tests, and the conditions governing germination were varied to suit the requirements, in so far as they could be determined. It is to be noted that germination in most cases was low. Table IV gives details on most of these plants and on certain other miscellaneous drug plants.

II

Dealers in crude drugs will many times lend valuable assistance in searching for and supplying seeds and plants. Importers with foreign representatives and the foreign merchants themselves will sometimes request their agents and collectors to assist in such matters. No great diversity of forms, however, can be secured through these sources. They are restricted to those of which the seed constitutes the medicinal part, or to those in which the seeds are likely to appear with other plant parts. The forms thus obtainable are mostly included in the preceding list, though better seeds are sometimes furnished by the dealers upon special request for fresh material.

III

It is sometimes possible to locate individuals in different countries who have become interested in the collection of rare seeds and plants. Such sources are extremely questionable. While some individuals can furnish much good material, there are others who, though expressing much interest, cannot be depended upon to supply the proper species. Numerous instances of this have been recorded, an example of which may be noted where an enthusiastic druggist of Texas supplied fine specimens of *Monarda* for henbane, which he claimed was growing luxuriantly in his section of the state.

Local drug collectors may be considered here rather than with crude drug merchants. More strictly speaking, they are a class by themselves with many peculiarities and limitations. They are mostly illiterate persons, who take instructions poorly and disregard them when once in the field. A close personal association with many of them has revealed the fact that they are only capable of accurately identifying a very small number of medicinal plants. These usually occur among the monotypic genera and, when two or more closely related species are in question, are usually collected indiscriminately. One of the most intelligent collectors observed repeatedly brought in specimens of various species of *Asclepias*, upon requests and instructions for *Apocynum cannabinum* and *Apocynum androsaemifolium*. *Apocynum cannabinum* when finally located was supplied upon requests for both of the two species. Only recently a negro quack, who is held in high repute by the colored element of a considerable section, supplied *Apocynum androsaemifolium* upon request for *Leptandra virginica*. Another form supplied for *Asclepias tuberosa* will have to be grown to maturity before it can be identified. One collector was shown potted specimens of golden seal (*Hydrastis canadensis*), and stone root (*Collinsonia canadensis*), and failed to recognize either of them. Twin leaf (*Jeffersonia diphylla*) is repeatedly offered by local dealers for genuine golden seal. Both the leaf and root structures of these forms are quite distinct.

IV

In so far as their collections will permit, the botanical gardens and other similar institutions are of great value in supplying

materials. Usually their collections of medicinal plants are comparatively small, but those which are obtainable are of high quality, and correctly classified. The liberal spirit of some of these stations is now restricted in some instances by government control. Such is the case with the buchu (*Barosma betulina*) of South Africa. To obtain seeds of this form direct from the Transvaal a long and tedious routine of grants, permits, etc., is necessary before they are allowed to be sent out of the country. On the other hand, such places as the Jamaica Public Gardens, Jamaica, the Kew Royal Gardens near London, England, the Royal Botanic Garden of Calcutta, India, the Botanic Garden and Museum of Natural History of Pará, Brazil, the Botanic Garden at Georgetown, British Guiana, and many others in foreign localities are usually willing to exchange or contribute materials for experimental purposes. Of no less distinction and willingness in this respect are the gardens at New York and St. Louis, the Office of Seed and Plant Introduction, and the Bureau of Plant Industry of the United States Department of Agriculture. However, it frequently happens that these excellent and widely separate stations fail to have the materials desired. At present, this condition exists with some unusually desirable species of the genus *Artemisia*.

V

Commercial seedsmen and nurserymen have so far proven the best sources of supply, though they do not always maintain the highest standards of nomenclature. It is encouraging in this respect to note a growing tendency on their part to list more of their materials under the specific technical names. However, great numbers of varietal or trade names are annually introduced through these channels, which cause much confusion and uncertainty. Sooner or later many of these must be reduced to synonymy. Much time and energy is consumed in varietal tests for determining these synonyms, and any movement which will reduce their number must be greatly appreciated. What is most desired in this respect is the retaining of the native and introduced forms under their original names, or at least the recording of varieties in such a manner that the original parents can be traced, and the pedigrees of the supposed new forms accurately obtained.

The catalogues of the most prominent seedsmen and nurserymen from the United States, England, France, Germany, and Japan have been examined for medicinal plants. In such an examination it was necessary to have clearly in mind some means of deciding whether or not a given form should be classed medicinal or non-medicinal. Certain limitations must be exercised in such a distinction, and a conservative'rather than a general attitude should be maintained. To follow the inclinations and suggestions of some authors would mean the consideration of an almost unlimited number of plants as possessing medicinal value. Practically, the list should not greatly exceed three hundred in number, and of these there are many included which are of doubtful value. In Bulletin No. 2, California State Board of Forestry, entitled "Pharmacal Plants and Their Culture," there is a context of one hundred and fifty-four pages, eight of which treat of the cultivation of medicinal plants in California. A portion of this small space is given up to such forms as sage, horehound, rosemary, marjoram, and dandelion. The greater bulk of the publication is taken up with a list of " Native and Introduced Medicinal and Poisonous Plants." The inclusion in this list of such forms as sugar maple, box elder, maidenhair fern, common edible mushroom (*Agaricus campestris*), wind flower, columbine, pawpaw, banana, garden beet, clematis, persimmon, California poppy, strawberry, holly, lemon, puffball, sorrel, cinquefoil, yucca and even corn, can hardly be explained. If such plants as the foregoing are to be considered medicinal, the list of three hundred would quickly grow to six hundred or more.

Based upon such a liberal classification, all seedsmen and nurserymen could be said to list medicinal plants regularly, and in large numbers, while as a matter of fact they fist but very few. Certainly such a. classification is not advisable, from either a practical or a scientific standpoint. The list which has been used as a means of dividing this material into medicinal and non-medicinal contains three hundred and eighty different forms, and includes all those that are commonly used by prominent manufacturers of pharmaceutical preparations.

A LIST OF SEEDSMEN AND NURSERYMEN WHOSE CATALOGUES HAVE BEEN EXAMINED FOR MEDICINAL PLANTS, AND THE NUMBERS OF SUCH FORMS LISTED BY THEM

Name of Firm	Location	Number Medicinal Forms Listed
Bash's Seed Store	Indianapolis, Ind.	25
P. J. Berckmans Co.	Augusta, Ga.	20
A. T. Boddington	New York City	12
Bobbink & Atkins	Rutherford, N. J.	53
Benary, Ernst	Erfurt, Germany	68
Biltmore Nursery	Biltmore, N. C.	45
W. Atlee Burpee & Co.	Philadelphia, Pa.	18
California Nursery Co.	Niles, Cal.	26
Childs, John L.	Floral Park, N. Y.	17
Dreer, Henry A.	Philadelphia, Pa.	47
Elliot Nursery	Pittsburgh, Pa.	33
Ferry, D. M., & Co.	Detroit, Mich.	4
Fottler, Fiske, Rawson Co.	Boston, Mass.	17
Gillett, Edward	Southwick, Mass.	58
Glen St. Mary Nurseries	Glen St. Mary, Fla.	6
Gregory & Son	Marblehead, Mass.	3
Isaac House & Son	Bristol, England	5
Peter Henderson & Co.	New York City	21
Horsford's Nurseries	Charlotte, Vt.	35
Haage & Schmidt	Erfurt, Germany	158
Kelway & Son	Langport, England	10
Medical Nursery	Calcutta, India	50
Livingston Seed Co.	Columbus, Ohio	4
C. C. Morse & Co.	San Francisco, Cal.	8
T. V. Munson & Son	Denison, Texas	4
Monroe Nursery Co.	Monroe, Mich.	16
Henry Mette	Quedlinburg, Germany	58
Oregon Nursery Co.	Salem, Ore.	10
Roumanille Lafayette père & fils	St. Remy de Provence, France	28
John A. Salzer Seed Co.	La Crosse, Wisc.	27
J. M. Thorburn & Co.	New York City	52
Vaughan's Seed Store	Chicago, Ill.	35
Watkins & Simpson	London, England	24
J. D. Webster	Chichester, England	15
Yokohama Nursery Co.	Yokohama, Japan	6

Based upon the number of important species listed, method and accuracy of nomenclature, class of material and general attitude the above list could be reduced to nine as follows: Haag & Schmidt, Benary, Mette, Medical Nursery, Gillett, Thorburn, Biltmore Nursery, Dreer, and Bobbink & Atkins. Materials have been obtained from five of these, and from eight of the others.

The following discussion will consider not only the propagation of this material, but also such related problems as continued growth, productivity, commercial value, hardiness, habitat, and ease of transplanting, cultivating, and harvesting.

The methods of propagation have been those of standard use. Corbett (4) divides these methods into the natural and artificial. The natural methods include reproduction by seeds, spores, rootstocks, stolons, suckers or root sprouts, bulbs, corms, and tubers. The artificial methods consist in reproduction by cuttings, layering, grafting, and budding. Necessary adjuncts to all of these methods are suitable greenhouses, cold frames, hot beds, and open field accommodations.

Propagation from seeds has been practiced wherever possible, and must in nearly all cases precede other methods. Seed propagation, however practical it may be, will not serve all purposes. In breeding experiments and improvement selections, it is often very desirable to multiply individual specimens by other means. Inbreeding for the purpose of obtaining uniform strains is often a long and laborious method, while vegetative reproduction would give the same results in a shorter interval of time. Latent tendencies are more quickly and accurately eliminated, necessary seed production is avoided, as well as the saving of much time in seeding and transplanting.

Open field methods of seeding have been found impracticable and in many cases impossible with many medicinal forms. This condition necessitates a wide deviation from most normal methods of cropping and leads to the necessary development of specialized systems. Little of an agricultural nature has been developed with these forms. Farwell (8) says that belladonna, henbane, digitalis, and aconite can be grown as easily as potatoes. Turner (23) gives directions for growing henbane, which are too general to be of any value. Saunder's (19) statements on the germination of seeds of medicinal plants are general, and include no methods or actual data. Henkel (10) says that digitalis offers no difficulties in cultivation, and advises sowing in the open field or in seed beds. True (22) advocates open field planting of digitalis. Kraemer (13), in his brief notice on seed germination, discourages open field sowing. Open field sowings of henbane, belladonna and digitalis have been

made for three successive years on well-prepared ground, and all have resulted in complete failures. Not enough plants for experimental purposes were obtained by the most careful attention.

Continued failures from open sowing of henbane are reported from England. Thirty years ago Holmes called attention to the difficulties in the cultivation of henbane. He mentioned the uncertainty of the crop in England, and the peculiarities in the germination of the seed. Again (11) in 1905 he mentions the uncertainty of the crop. Ransom (17) in 1902 claims that it is difficult to obtain a good crop of this drug in Britain. Henkel (10) later calls attention to the uncertainty in seed germination. Turner (23) in his directions for growing henbane is encouraging in the extreme. In his opinion it is not a difficult crop to handle. Repeated tests in the open field have resulted in failures. Fair germination was obtained in one instance, but the seedlings could not compete with common weeds until large enough for cultivation. Seed tests carried on under glass indicate that germination is of high percentage, uniform and fairly regular for seeds from different sources.

With some of the older drugs in cultivation, propagation and cultural systems have been highly developed. Examples of this may be found in the excellent notes of Weddell (24) on the nurseries, cultivation, harvesting and curing of coca, of Lumsdaine (15) on the cultivation of nutmegs and cloves in Bencoolen, of Eatwell (7) on the methods of cultivation, collecting, and curing of opium, and the influence of soil and climate upon the yield and quality of the product, and of DeVry (6) on cinchona.

There are few authentic data or directions, however, upon the propagation and cultivation of the more important forms which are adapted to this country. This list might well include such forms as belladonna, henbane, stramonium, digitalis, arnica, larkspur, valerian, san tonica, veratrum, hellebore and others. It is evident that methods would have to be developed to suit the conditions of soil and climate, and at the same time be varied to meet the purposes of the work. That is, commercial production might be possible under a system which would be worthless for experiments on plant breeding and improvement.

In the following discussions the questions of propagation have

been taken up in conjunction with other problems, and have only been developed as progress might demand. The work has been done for the purpose of determining the practicability of growing certain drug plants upon a commercial scale, and the possibility of improving them through an application of the methods of plant breeding. All seed tests have been of a practical nature, and but little of the great mass of material upon the effects of various reagents and influences upon germination has been used. This material so far seems to have resulted in no new general laws applicable to commercial growers. Experiments upon the effects of light and darkness (Heinricher, g) upon seed germination, temperature (Reynolds, 18) in relation to germination, treatment with warm water (Jensen, 12), sterilization of soil (Stone & Smith, 21), copper sulphate treatment (Bréal & Giustiniani, 2), electrical effects (Monahan, 16), soaking in chlorine water (Spatschil, 20), soil temperature (Brown, 3), action of ether and chloroform (Becquerel, 1) and delayed germination (Crocker, 5), have resulted in many data but few generalizations. Specific gravity tests, sterilized soils and the sulphuric acid treatment (Love & Leighty, 14), have been used successfully and might be recommended for practical purposes. The forms under consideration and the results so far obtained are as follows:

DIGITALIS

More or less uncertainty exists as to the exact botanical source of this drug. The comparative medicinal value of the leaves from wild and cultivated forms, and the disputed methods of collection, curing and packing are unsettled questions of considerable importance. The comparative value of the many species and horticultural varieties, their ease of culture, relative yield of crude drug, their flowering periods, hardiness and duration of growth are additional problems which must be investigated before the genus can be made to yield its best to the manufacture of medicine.

Open field sowing was tried several times during two successive years. These tests were carried out both under practical field conditions and in ideally prepared seed beds. The results were complete failures and open seed sowing under field conditions

cannot be recommended. After this preliminary work, the open field methods were abandoned for the more reliable greenhouse methods.

Seeds of twenty-seven varieties were obtained for experimental plantings. These were germinated (see Table I) in seed pans under glass, and transplanted to flats as soon as the second leaves were visible. These flats were retained in a cool greenhouse of 50 degrees night temperature, and 60 degrees day temperature, until March 1, when they were transferred to cold frames. The sashes of these frames were of double glass construction, and required little attention until the latter part of April. Then the sashes had to be removed during the day to prevent burning of the foliage, and to thoroughly harden off the young seedlings before transplanting to the field.

Transplanting to the open field was done mostly by inexperienced labor, and during dry weather accompanied by strong winds. The inexperienced labor was used as a means of determining the transplanting qualities of these forms, and the unfavorable weather only rendered this test more severe. After transplanting, the young plants were watered twice on consecutive days, and then left to the influence of natural conditions. Cultivation was commenced early, and repeated frequently throughout the growing season. The soil was a poor, stiff, clay loam, but all forms of the digitalis made excellent growth, as is evidenced by the amount of dry leaf produced by some average individual plants. Some of these yielded as follows:

Digitalis maculata Iveryana, a strong and robust form, 392 grams, *Digitalis gloxinioides* 170 grams, Digitalis Ivery's spotted 209 grams, and *Digitalis alba* 1,721 grams. In obtaining the comparative yield (see Table I) of all the varieties, ten average plants were selected, and all the leaves collected from them, and thoroughly air dried. The figures representing comparative yield of *Digitalis alba, D. purpurea* and *D. canariensis,* Watkins; *D. sibirica, D. lanata*, and *D. ambigua,* Horsford ; and *D. gloxiniaeflora rosea*, Dreer, are all low on account of early collection. Those for the other forms, however, are accurate enough for all practical purposes. The comparative toxicity as given in the table is based upon figures obtained by the one hour frog heart method for testing *Digitalis*

and its preparations. The value "one" represents the greatest toxicity, while the numerical increase indicates a proportional decrease in toxicity. Thus the weakest sample tested (Digitalis *gloxiniaeflora alba)* has a toxicity of 6.3.

Another object of the *Digitalis* study was to test the effects of hybridization upon medicinal value. For this work, it was very desirable to bring the various species and varieties into flower as soon as possible. Early seed sowing augmented by a rather rapid growth in the greenhouse and by a slow hardy growth in the cold frames, as well as by a late and unusually favorable season, resulted in a number of flowering plants from several species and varieties (see Table II). For the purpose of obtaining early flowering plants upon which to begin the work of inbreeding and hybridization, a number of one year old plants were purchased from A. T. Boddington. These began flowering early, and furnished material throughout the season. Various combinations were tried, a number of which were successful, and seedlings are already being propagated in an effort to bring them into flower the first year. Thus any breeding operations can be annually continued or discontinued as the results may indicate, whereas these forms under the usual conditions of propagation would require two years to reach maturity.

It has also been noted that a small number of annual forms have appeared in the late plantings of several species and varieties, and especially where large numbers of plants were used. In all cases these have been inbred. The resulting progeny of these inbred annuals will be closely observed for the reappearance of annual forms.

Root division and propagation of lateral buds have both been tried with several varieties of Digitalis (see Table III). It was hoped that clonal varieties could be obtained in this manner. Uniformity of individuals and their behavior to varied soil and climatic conditions could then be studied with greater accuracy. Lateral buds, with and without roots, were carefully removed. Those removed during summer, fall and win.ter were extreme1y hard to start, whether they bore roots or not. Sand proved to be the best material for this purpose. However those made in early spring from plants left in the open have yielded a large percentage of

plants. Side cuttings, with and without roots, made February 21, 1913, had rooted in sand in the greenhouse March 20, 1913.

BELLADONNA

The propagation of belladonna was first attempted through open field sowing. Successive trials under varied field conditions with seed fromseveral different sources resulted incomplete failures. Fall sowing of imported seed upon a carefully prepared seed bed gave the following result. Seed planted September 3, 1912, fair germination October 21, 1912. Seed collected from growing plants August 15, 1912, planted September 3, 1912, fair germination October 21, 1912.

Greenhouse conditions were then tried, which were practically the same as those for digitalis, except that the seed pans used were more carefully protected from alternate degrees of moisture and dryness. See Table IV for germination data, and Tables V and VI for the influence of certain seed treatments upon germination.

The belladonna seedlings transplant with considerable ease and with practically no loss. Damping off is not so frequent as with digitalis and henbane. Sterilized soil and careful watering greatly reduce this trouble in all cases. The belladonna seedlings were retained in the greenhouse in flats until well established, and were then transferred to the cold frames. This was done on some occasions as early as March 19. Observations at this time showed a temperature of 46 degrees inside the frames, with the outside temperature below freezing. Outside night temperatures of 18 degrees caused no injury to the seedlings under the unprotected double glass sash. Seedlings transplanted directly into the frames in stiff clay soil made slower growth than those in the better soil of the flats, but produced hardier and more stalky plants, which transplanted to the open with much greater ease and certainty. They also made better subsequent growth than those in the flats. They required much less attention while in the frames, having to be watered only occasionally, while those in the flats dried out rapidly as the season advanced, and demanded considerable attention. Seedlings retained in the greenhouse in flats until May 10 were tender and succulent and wilted badly when transferred to the open field. From thirty to forty per cent. were lost

during this second transplanting, while with those from the cold frames this loss was scarcely appreciable.

The successful propagation of the belladonna plant was only a necessary preliminary procedure to other more important problems. It was desired to observe this form under cultivation, to study its commercial production and the possibilities of developing a strain which would produce a uniformly higher yield of alkaloids than the ordinary commercial drug.

The first of these problems was accomplished through seed propagation. No difficulty was experienced in obtaining an abundance of plants after indoor methods of propagation were adopted. Large luxuriant plants were obtained from seed sown March 8, 1912, and were flowering by July 12. It is interesting to note here that the plants which had been transplanted directly from the seed pans to the poor soil in the cold frames were the first plants to commence flowering. The plants at this time (July 12) were from two to three feet tall, and much branched. Ransom (17) says that belladonna grown in England from seed sown in early spring produces little if any herb worth cutting the first year.

It is now believed that two profitable harvests can be obtained during one growing season, from plantings made January 1st of the same year. The belladonna plant is an herbaceous perennial, but on account of its susceptibility to winter killing in this climate, it may have to be grown as an annual. 1724 plants were left in the open without protection as a test for hardiness and as a means of obtaining individual plants of unusual hardiness from which to develop a strain more adapted to this climate. September 24 the entire herbaceous portion was removed from 1414 of these plants, the remaining 310 being left undisturbed. Twelve clumps of roots were lifted November 7, 1912, and placed in the cold frames with no protection except the double glass sash. The sash was put on at this time, and left closed until March 31, 1913, when the plants were first observed. At this time they were all bearing vigorous sprouts. Those left in the open were showing no growth on this date. These were again observed May 1, and the following conditions noted :

Number of plants, from which herbaceous portion had been removed, showing growth, 44.

Number of plants, which had been left undisturbed, showing growth, 307.

The second object of the belladonna investigation, viz., the attempt to produce a strain which would yield a uniformly higher percentage of alkaloids than the commercial drug, involves another method of propagation. In this case, individual plants must be examined for their property of yielding certain percentages of alkaloids. It is desirable to propagate promising individuals in such a manner that the high yielding character will be uniformly transmitted to the offsprings. As yet it is not known how such a character behaves. Alkaloids are not essential products of metabolism, and the inheritance of the property of producing a large percentage of such products is indeed questionable.

To investigate this point, both seed and vegetative propagation of pure strains must be practiced. The behavior of the character in these pure strains and their progeny will throw much light on the possibility of developing, propagating, and maintaining high yielding varieties through the practice of breeding.

If the property of an individual plant to produce a definite amount of alkaloids when grown under uniform conditions, behaves in the same manner as many external characters, the propagation of pure bred strains by the vegetative method should yield uniformly according to selection.

To test this possibility, it was necessary to follow the methods of the florist in the propagation of cuttings in sand. This was done both in the greenhouse and in the open under cheese cloth shade. In the greenhouse the open sand bed was tried as well as the glass-covered bed recommended by Bailey. The open bed was also tried, with the cheese cloth shade. The best results in the greenhouse were obtained with the open bed under the influence of a mild bottom heat, and very careful watering. Sterile sand had to be used to prevent a total loss of the cuttings from the attack of a very small white worm, which fed on the lower ends of the cuttings, and prevented callousing until decay would commence. The best outdoor results were obtained from the use of the cold frames protected with cheese-cloth shades. Top cuttings made from the more mature wood of the open grown plants strike root more readily than those from the tender succulent wood of plants grown in the greenhouse.

Table III gives results obtained by the vegetative method of propagation for belladonna and other miscellaneous forms. Open field seeding has been found practical for such forms as stramonium *(Datura Stramonium),* cannabis indica *(Cannabis sativa)*, larkspur *(Delphinium Consolida),* and lappa (*Arctium Lappa*). This list can probably be greatly enlarged as other forms are tested.

Various species and varieties of the genus *Datura* are being investigated in the same manner as belladonna and digitalis. Fifty individual plant assays have been made from plantings of *Datura Stramonium* and *Datura Tatula.* These indicate that the application of plant breeding methods to the improvement of medicinal plants may be successful, and extremely practicable. Averages of 50 per cent. and 60 per cent. have been obtained from the progeny of selected parent plants of *Datura Stramonium* and of 49 per cent. and 62 per cent. from *Datura Tatula* as compared with averages of 28 per cent. and 35 per cent. obtained respectively from wild plants of these two species. Individual plants have been found which assay as high as 65 per cent. for the *D. Stramonium* and 77 per cent. for *D. Tatula.* Such individuals are used for propagating purposes. Again, as in the case of belladonna, it is a question of inheritance that must determine the method of propagation or the advisability of attempting to perpetuate these high yielding individuals for commercial purposes.

In the foregoing, propagation has only been considered as a necessary preliminary procedure to other more comprehensive problems. A sufficient number of methods for propagating various classes of plants has been developed to suit the present need of medicinal plant growers. These have been largely the result of certain demands upon well-established horticultural forms, and their extended use is only a matter of application.

Their application herein described has furthered investigations not otherwise possible. The results obtained from their application, the continuation of other related problems, and the objects in view, have all been stated. The related problems such as commercial production, the testing of different species and varieties, and their improvement by breeding and selection, have an unquestionable economic value, the solution of which will lend

TABLE I

FIELD RECORD

Species or Varieties	Source	Date Planted	Date Germinated	Per Cent. Germination	Date First Transplanting	Number Plants Used	Date Second Transplanting	Number Transplanted to Field	Number at End of Season, co-31-12	Samples Collected	Per Cent. Loss in Drying	Comparative Toxicity	Comparative Yield of Dry Drug
		1912	1912		1912		1912			1912			gm.
Digitalis purpurea rosea	Boddington	2–6	2-15	go	3–13	440	5–20	396	358	9–15	82	1.3	1,845
Digitalis purpurea rubra	Boddington	2–6	2–15	70	3-18	330	5-2 1	264	226	9–15	82	1.5	1,656
Digitalis lanata	Boddington	2–6	2–19	60	3-12	209	5-25	88	87	9–19	76	1.0	1,008
Digitalis Ivery's spotted	Ferry	2–29	3–11	60	3-29	330	5-24	264	244	IO-I I	86	1.8	2,090
Digitalis mixed	Salzer	3-7	3-18	90	4-2	330	5-25	I76	153	10–18	82	2.5	1,755
Digitalis **sp.**	Yokohama	3-5	3-18	80	4-5	330	5-23	264	239	10–18	81	3.0	1,495
Digitalis lutea	Benary	3-22	4-1	60	4–11	330	5-22	264	256	I I-I	70	2.1	554
Digitalis macranthus	Benary	3-22	4-1	70	4–11	330	5-23	264	231	I I-I	67	2.6	430
Digitalis Buxbaumi	Benary	3-22	4-1	70	4–10	330	5-23	264	253	I I-I	74	1.6	994
Digitalis purpurea maculata superba	Benary	3-22	4-1	60	4–11	330	5-25	I76	168	I I-I	77	1.6	1,360
Digitalis purpurea	Oregon	2–19	3-1	60	4-1	1390	5–10	1300	952	7-14	76	3.0	425
		1911	1911										
Digitalis alba	Watkins	I I-22	12-1	90	r-30	345	5-20	264	193	7-25	78	2.3	391
Digitalis purpurea	Watkins		12-1	90	1–30	351	5-25	88	83	7-25	80	3.0	312
		1912	1912										
Digitalis canariensis	Watkins	1-4	1–15	70	2-15	440	5-2 1	264	244	8–15	47	1.6	266
Digitalis monstrosa	Watkins	2-7	2-15	80	3–15	440	5-20	396	349	9–15	84	2.6	1,150
Digitalis sibirica	Horsford	2-8	2–19	80	3-1 1	220	5-21	396	380	7–28	72	1.8	149
		1911	1911										
Digitalis lanata	Horsford	12-20	12-28	40	2–6	99	5-25	I76	173	7–28	76	1.3	219
Digitalis ambigua	Horsford	12-21	12–29	40	2-14	200	5–21	264	243	7–29	66	1.8	173
		1912	1912										
Digitalis gloxinioides	Horsford	2-7	2-16	80	3-4	450	5-20	616	552	9–16	82	1.5	1,850
Digitalis gloxiniaeflora rosea	Dreer	1-8	1–19	80	2-15	100	5-20	264	213	8–19	74	2.0	664
Digitalis monstrosa	Dreer	2-7	2-15	90	3-1	511	5-20	428	394	9–15	82	1.8	1,645
Digitalis grandiflora	Dreer	2-7	2–19	60	3-27	330	5-24	264	220	9–19	68	3.0	351
Digitalis maculata Iveryana	Boddington	1-17	1-25	80	2-13	333	5-2 1	264	228	8-35	84	1.6	1,050

TABLE I (Continued)

FIELD RECORD

Species or Varieties	Source	Date Planted	Date Germinated	Per Cent. Germinated	Date First Transplanting	Number Plants Used	Date Seeond Transplanting	Number Transplanted to Field	Number at End of Season, 10-31-12	Samples Collected	Per Cent. Loss in Drying	Comparative Toxicity	Comparative Yield of Dry Drug
Digitalis gloxiniaeflora purpurea	Boddington	1-30	2-10	70	3-7	440	5-20	352	318	g-10	84	1.5	1,815
Digitalis gloxiniaeflora lutea	Boddington	1-30	2-13	60	3-6	440	5-22	264	262	9-13	74	1.6	882
Digitalis gloxiniaeflora lilicina	Boddington	2-6	2-14	80	3-8	440	5-22	308	272	9-14	80	1.6	1,715
Digitalis gloxiniaeflora alba	Boddington	2-6	2-15	80	3-16	330	5-24	308	224	9-15	82	6.3	1,475
Digitalis purpurea alba	Boddington	2-6	2-15	80	3-12	440	5-20	396	334	9-15	84	1.6	1,855

TABLE II

DATES OF FLOWERING AND NUMBER OF PLANTS IN FLOWER

Variety	Source	Date Planted	Jul. 15	Jul. 20	Jul. 25	Jul. 30	Aug. 10	Aug. 10	Sep. 1	Sep. 20	Oct. 15	Used
		1911										
Digitalis lanata	Horsf ord	12-20						1		2	2	97
Digitalis ambigua	Horsford	12-21	1	17	35	49	54	87	151	217	220	233
		1912										
Digitalis canariensis	Watkins	1-4									2	224
Digitalis gloxiniaeflora lutea	Boddington	1-30		1	1			3	11	68	95	386
Digitalis purpurea rosea	Boddington	2-6										358
Digitalis purpurea alba	Boddington	2-6					1					334
Digitalis gloxinioides	Horsford	2-7					4		5	9	10	383
Digitalis monstrosa	Watkins	2-7					1	2			2	349
Digitalis grandiflora	Dreer	2-7		1	2		5	32	113	189	239	240
Digitalis sibirica	Horsford	2-8								6	20	294
Digitalis Iverys spotted	Ferry	2-29									1	344
Digitalis sp.	Yokohama	3-5									5	239
Digitalis macranthus	Benary	3-22		2	3		16	81	161	217	222	231
Digitalis lutea	Benary	3-22								1	3	256
Digitalis Buxbaumi	Benary	3-22							1	7	25	319

TABLE III

PROPAGATION BY CUTTINGS

Name	Source	Number Started	Date Started	Number Rooted	Date Rooted	Method
			1912		1912	
Belladonna	Field plants	26	7–31	0		Greenhouse, open sand bed
Belladonna	Field plants	17	8–5	1	8-19	Greenhouse, open sand bed
Belladonna	Field plants	24	8-1	0		Greenhouse, open sand bed.
Belladonna	Greenhouse plants	76	8-1d	73	6-6	Greenhouse, bottom heat.
Belladonna	Greenhouse plants	25	8-1	0		Greenhouse, bottom heat.
Belladonna	Greenhouse plants	35	8–14	0		Greenhouse, bottom heat.
Coleus control	Greenhouse plants	6	8–14	4	8–26	Greenhouse, bottom heat.
Coleus control	Greenhouse plants	19	8–22	0		Greenhouse, bottom heat.
Coleus control	Greenhouse plants	28	8-22	0		Greenhouse, bottom heat.
Coleus control	Greenhouse plants	5	1–30	0		Greenhouse, bottom heat.
Coleus control	Greenhouse plants	121	1–22	0		Greenhouse, glass covered bed
Coleus control	Greenhouse plants	9-9	1-29	0		Greenhouse, open sand bed
Coleus control	Greenhouse plants	42	1–29	0		Greenhouse, open sand bed
Coleus control	Field plants	220	9-d	107		Cold frames, cheese cloth shades
Coleus control	Field plants	180	9-6	101		Cold frames, cheese cloth shades
Digitalis canariensis	Field plants	50	6–10	19	6-29	Greenhouse, open sand bed
Digitalis canariensis	Field plants	40	7–13	0		Greenhouse, cheese cloth shade
Digitalis canariensis	Field plants	21	7–31	0		Greenhouse, open sand bed.
Cytisus scoparius	Greenhouse plants	20	8-8	12	6-29	Greenhouse, open sand bed
Cytisus scoparius	Greenhouse plants	55	6-29	30	8–30	Greenhouse, open sand bed
Nasturtium control	Greenhouse plants	7	6-29	6	7–8	Greenhouse, open sand bed
Cereus grandiflorus	Crude drug	36	6-8	18	6-29	Greenhouse, open sand bed
Marshmallow	Field plants	11	7–31	1	8-19	Greenhouse, open sand bed
Solanum Dulcamara	Field plants	7	8–5	4	8–30	Greenhouse, open sand bed
Vanilla	Greenhouse plants	21	6–20	1	8–20	Greenhouse, open sand bed
Digitalis	Field plants	6	2–21	4	3–18	In sand under bell glass.

TABLE IV

SEED GERMINATION

Name	Source	Date Planted	Date Germinated	Germination	Conditions
Atropa Belladonna	Greenhouse	12-21-11	1-24-12	Good	Greenhouse
A tropa Belladonna	Comm. sample	12-11-11	1-26-12	Uneven-fair	Greenhouse
Atropa Belladonna	Greenhouse	1- 4-12	2- g-12	Good	Greenhouse
A tropa Belladonna	Comm. Lot.	2- g-12	3- I-12	Fair	Greenhouse
Atropa Belladonna	Comm. Lot	2-19-12	3- 8-12	Poor	Greenhouse
Atropa Belladonna	Dept. Agri.	I-10-12	2-20-12	Very good	Greenhouse
A tropa Belladonna	Dept. Agri.	2-20-12	3-10-12	Fair	Greenhouse
Atropa Belladonna	Aug. & Geo. Fischer	2-26-12	3-21-12	Good	Greenhouse
Atropa Belladonna	Cult. plants	12-24-12	12-20-12	Good	Greenhouse
Atropa Belladonna	Haag & Schmidt	2-22-13	3-23-13	Poor	Greenhouse
A tropa Belladonna	Select plant	2-25-13	3-19-13	Poor	Greenhouse
Atropa Belladonna	Select plant	2-25-13	3-19-13	Poor	Greenhouse
Atropa Belladonna	Select plant	2-25-13	3-19-13	Poor	Greenhouse
Atropa Belladonna	Select plant	2-25-13	3-27-13	Poor	Greenhouse
Atropa Belladonna	Select plant	2-25-13	3-27-13	Poor	Greenhouse
Atropa Belladonna	Aug. & Geo. Fischer	9- 3-13	10-21-12	Fair	Open field
Atropa Belladonna	Cultivated plants	g- 3-12	10-21-12	Fair	Open field
Nicandra physaloides	Haag & Schmidt	2-22-12	3- 7-12	Good	Greenhouse
Hyoscyamus niger	Benary	2-22-12			
Hyoscyamus niger	Benary	3-22-12	4- 3-12	Fair	Greenhouse
Hyoscyamus niger	Aug. & Geo. Fischer	3-22-12			
Hyoscyamus niger	Aug. & Geo. Fischer	2-12-12	2-23-12	Good	Greenhouse
Hyoscyamus niger	Aug. & Geo. Fischer	2- 7-12	2-14-12	Good	Greenhouse
Hyoscyamus niger	Haag & Schmidt	2-25-12		No result	Greenhouse
Hyoscyamus niger	Haag & Schmidt	2- 7-12		No result	Greenhouse
Hyoscyamus niger	Yokohama, Japan	2-25-12	3-20-12	Fair	Greenhouse
Hyoscyamus niger	Yokohama, Japan	3-14-13	4- 3-13	Poor	
Hyoscyamus sp	Watkins & Simpson	5- 5-13		No result	Greenhouse
Hyoscyamus annual	Cultivated plant	5- 3-13	3-27-13	Good	Greenhouse
Hyoscyamus orientalis	Haag & Schmidt	2-10-13	2-27-13	Poor	Greenhouse

TABLE IV *(Continued)*

SEED GERMINATION

Name	Source	Date Planted	Date Germinated	Germination	Conditions
Hyoscyamus muticus	Wheeler & Son	2-24-13	3- *8-13*	Fair	Greenhouse
Hyoscyamus muticus	Aug. & Geo. Fischer	3-20-12		No result	Greenhouse
Hyoscyamus sp	Vaughn	4-15-10		No result	Greenhouse
Glycyrrhiza glabra	Haag & Schmidt	4-30-I 2	5- g-12	Very poor	Greenhouse
Glycyrrhiza glabra	Haag & Schmidt	12-24-12	I- *2-13*	Poor	Greenhouse
Bryonia alba	Haag & Schmidt	12-24-12		No result	Greenhouse
Bryonia dioica	Haag & Schmidt	12-24-12		No result	Greenhouse
Cinchona officinalis	Haag & Schmidt	2- 8-13	*3-28-13*	Poor	Leaf mould
Cinchona Calisaya	Haag & Schmidt	2- 8-13		No result	Leaf mould
Cinchona succirubra	Haag & Schmidt	2- 8-13		No result	Leaf mould
Erythroxylum Coca	Haag & Schmidt	2- 8-13		No result	Leaf mould
Veratrum album	Haag & Schmidt	2- 8-13		No result	Leaf mould
Veratrum viride	Haag & Schmidt	2- 8-13		No result	Leaf mould
Veratrum nigrum	Haag & Schmidt	2- 8-13		No result	Leaf mould
Colchicum autumnale	Haag & Schmidt	2- 8-13		No result	Greenhouse
Gentiana lutea	Haag & Schmidt	2- 8-13		No result	Greenhouse
Laurus Cinnamomum	Haag & Schmidt	2- 8-13		No result	
Santalum album	Haag & Schmidt	2-10-13		No result	
Strychnos Nux-vomica	Haag & Schmidt	2-10-13		No result	
Convolvulus Scammonia	Haag & Schmidt	2-10-13	*2-18-13*	Poor	
Citrullus Colocynthis	Haag & Schmidt	2-10-13	3-28-13	Poor	
Piper nigrum	Haag & Schmidt	2-10-13		No result	
Quillaja Saponaria	Haag & Schmidt	2-10-13		No result	
Scilla maritima	Haag & Schmidt	2-10-13		No result	
Aloe ferox	Haag & Schmidt	2-10-13		No result	
Archangelica officinalis	Haag & Schmidt	3-14-13		No result	Greenhouse
Anthemis nobilis	Haag & Schmidt	3-14-13	3-19-13	Good	Greenhouse
Arnica montana	Haag & Schmidt	3-14-13	3-2 I-13	Fair	Greenhouse
Levisticum officinale	Haag & Schmidt	3-14-13		No result	Greenhouse
Pyrethrum cinerarifolium	Haag & Schmidt	3-14-13	3-24-13	Good	Greenhouse
Carthamus tinctorius	Haag & Schmidt	3-14-13	3-18-13	Good	Greenhouse
Foeniculum vulgare	Haag & Schmidt	3-14-13	3-24-13	Good	Greenhouse

TABLE IV (*Continued*)

SEED GERMINATION

Name	Source	Date Planted	Date Germinated	Germination	Conditions
Elettaria Cardamomum	Comm. Sample	12-27-12		No result	Greenhouse
Delphinium Staphisagria	Comm. Sample	12-27-12	r-20-13	Poor	Greenhouse
Grindelia robusta	U. S. Dept. Agr.	2-I I-13	2-15-13	Good	Greenhouse
Insect flowers	Comm. Lot	2-I I-13		No result	Greenhouse
Strophanthus sp.	Comm. Lot	2-q-13		No result	Greenhouse
Strophanthus sp.	Comm. Lot	2-19-13	3- 5-13	Poor	Greenhouse
Althaea officinalis	U. S. Dept. Agr.	2-22-13	3- 5-13	Good	Greenhouse
Berberis Aquifolium	Commercial	3-10-13	4- 3-13	Fair	Greenhouse
Conium sp.	Comm. Lot	5- 5-13	3-20-13	Good	Greenhouse
Theobroma Cacao	Jamaica	3-14-13		No result	Greenhouse
Valeriana officinalis	Dreer	3-27-13		Good	Greenhouse
Apium Petroselinum	Comm. Lot	4- 4-13	4-17-13	Good	Greenhouse
Amomum Melegueta	Comm. Lot	4- 4-13		No result	Greenhouse
Apium graveolens	Comm. Lot	4- 4-13	4-16-13	Good	Greenhouse
Coriandrum sativum	Comm. Lot	4- 4-13	4-18-13	Good	Greenhouse
Chenopodium ambrosioides	Comm. Lot	4- 4-13	4-21-13	Good	Greenhouse
Carum Carvi	Comm. Lot	4- 4-13	4-17-13	Fair	Greenhouse
Delphinium Staphisagria	Comm. Lot	4- 4-13		No result	Greenhouse
Lobelia inflata	Comm. Lot	4- 4-13		No result	Greenhouse
Foeniculum vulgare	Comm. Lot	4- 4-13		No result	Greenhouse
Foeniculum vulgare	Comm. Lot	4- 4-13		No result	Greenhouse
Schoenocaulon officinale	Comm. Lot	4- 4-13		No result	Greenhouse
Pimpinella Anisum	Comm. Lot	4- 4-13		No result	Greenhouse
Citrullus Colocynthis	Comm. Lot	5- I-12		No result	Greenhouse
Aristolochia Serpentaria	Comm. Lot	5- 2-12		No result	Greenhouse
Schoenocaulon officinale	Comm. Lot	5- 8-12	7- 8-12	Poor	Greenhouse
Amomum Melegueta	Comm. Lot	5- 8-12	5-20-I 2	Fair	Greenhouse
Strophanthus sp.	Comm. Lot	5- 8-12			Greenhouse
Datura ferox	Haag & Schmidt	5-28-12	6- 4-12	Good	Greenhouse
Strophanthus Kombe	Comm. Sample	6-18-12			Greenhouse
Strophanthus hispidus	Comm. Sample	6-18-12			Greenhouse
Citrullus Colocynthis	Comm. Sample	6-18-12	7- 8-12	Poor	Greenhouse

TABLE V

EFFECT OF SEED AND SOIL TREATMENT ON GERMINATION

Name	Date Planted	Date Germinated	Germination	Treatment
Belladonna.	2-6-12	3 - 2-1 2	Good	Water
Belladonna.	2-5-12	3 - 5-12	Good	Warm water
Belladonna.	2—7—12	2-26-12	Very good	Warm water
Belladonna.	2—7—12	2-26-12	Very good	Warm water
Belladonna.	2-5-12	3-25-12	Good	Warm water
Belladonna.	2-6-12	3 - 2-1 2	Poor	Untreated

TABLE VI

CONCENTRATED SULPHURIC ACID TREATMENT FOR BELLADONNA

	Planted	Germ.	No. Seedling	Date	No. Seedling	Date	No. Seedling	Date	No. Seedling	Date	No. Seedling
	1913	1913		1913		1913		1913		1813	
Untreated.	2-14			3–13	3	3–19	3	3-28	14	4-8	24
Treated 5 mi..	2-14	3-5	2	3–13	4	3–19	10	3-28	27	4-8	36
Treated 10 mi.. ..	2-14	3-5	3	3–13	11	3–19	46	3-28	125	4-8	138
Treated 15 mi.. ..	2-14			3–13	3	3–19	15	3-28	32	4-8	31

much to the demands for better and more precise medicinal products.

INDIANAPOLIS, INDIANA.

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