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THE CULTIVATION OF BELLADONNA IN CALIFORNIA

BY

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THE CULTIVATION OF BELLADONNA IN CALIFORNIA

By ALBERT SCHNEIDER*

Belladonna is an important drug plant, and is peculiarly suited to the climatic conditions of the coast regions of California. The following outline of cultural methods is based upon numerous field tests, many of which were carried out on a commercial scale. The general results of these tests have demonstrated that belladonna can be grown successfully and profitably, provided the enterprise is rightly undertaken. A close adherence to the suggestions herein given, it is believed, will be followed by reasonable success.

CALIFORNIA EXPERIMENTS

The California experiments are especially interesting, first, because of the rather wide range of experience which they represent, and second, because the details of the successful commercial growing of belladonna have been fully worked out. It is therefore desirable to relate these experiences in detail for the benefit of those interested in the commercial growing of this drug.

In 1903 some belladonna plants were started in the garden of Medicinal Plants,[1] in Golden Gate Park, San Francisco. The soil in which this belladonna was grown is "made soil," consisting of loam which had been hauled in and mixed with the sand which formed the base of Golden Gate Park. These plants received but little care, yet thrived well. The second year's growth made its appearance late in January and the young shoots were not injured by a slight frost. The third and fourth years' growths were better than the growth of the second year. Several dried samples of stems and leaves submitted to Johnson & Johnson (F. B. Kilmer) for analysis showed a high yield of alkaloids. Analyses made at the California College of Pharmacy showed the same high yield, ranging from 0.40 to 0.82 per cent in the leaves, and 0.50 per cent in the stems, as given by Kilmer.

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[1] This garden was abandoned later, due to the lack of funds necessary for its maintenance.

In 1906 arrangements were made to carry on tests with belladonna at the experimental gardens of the College of Agriculture of the University of California, under the direction of R. E. Mansell, in charge of the field experiments. Cold-frame seeding was done in December, 1906, and about 200 young plants were transplanted in the month of May, 1907, into rather poor, inadequately prepared soil (clay, adobe, and gravel) on top of a ridge. This soil was hard, and dry, and there were no arrangements for irrigating. Naturally the plants made a very poor growth and many were killed by drought and weeds. Those which survived flowered in August. In December, 1907, some of the surviving plants were transplanted into another plot in which the soil was even poorer than in the one from which they were taken, and not one plant survived the season of 1908, a season of very high rainfall. These tests demonstrated that unless belladonna is well rooted at the time of transplanting (December to March) it cannot survive the dry season (May to early December) without irrigation. The experiments also proved that after the plant is once well rooted, it is highly resistant to drought.

In 1906 and 1907 some tests were made by the writer in a small garden at Salinas, California. Seeding was done in the open on January 14, 1906, and the first seedlings appeared on the 2nd of March. The soil was of the adobe variety, well fertilized with old stable manure, and well cultivated. The rainfall of the season was heavy. The plants made an excellent growth, flowering in July. This plat also received a top-dressing of lime at the time of seeding.

Other small plantings were made at Ross Valley by F. A. Hund, at Los Angeles by George A. Hill, and by B. Phillip at Alameda.

The sum total of results from the small experimental plantings above referred to led to the conclusion that certain areas of the coast region are peculiarly suited to the growing of belladonna.

In 1907 arrangements were made with the firm of Johnson & Johnson through their representative, F. B. Kilmer, to conduct some belladonna tests on a commercial scale. The writer, with the co-operation of Mr. Kilmer, was asked to make all arrangements for these tests. During the months of July, August, and September of the year referred to, the Salinas Valley, Pajaro Valley, Santa Clara Valley and the San Francisco Bay regions were visited, and a comparative study made of soil and climate. After careful deliberation a tract of thirty-two acres in the Castro Valley, near Hayward, Alameda County, was selected. The soil of the chosen plat was rich medium adobe and sedimentary loam, uniform in quality and not much overrun by weeds (the morning glory being the most noticeable among them). Big

crops of tomatoes had been grown in the field for two years preceding. The average seasonal rainfall for this small valley is about 20 to 22 inches. The surrounding low hills give some protection against the coast winds and also add to the soil moisture by slow seepage.

The following is a brief synopsis of the cultural operations for the season of 1907 and 1908.

Plowing was begun as soon as the first rains had moistened the soil sufficiently (December 14 to 25). A double-disc plow was used, going to a depth of nine inches. The soil was then double-disced and double harrowed. On December 17 seeding was begun. A No. 5 "Planet Jr," seeder was used, set to drill about three-fourths of a pound to the acre; seeding to a depth of one-

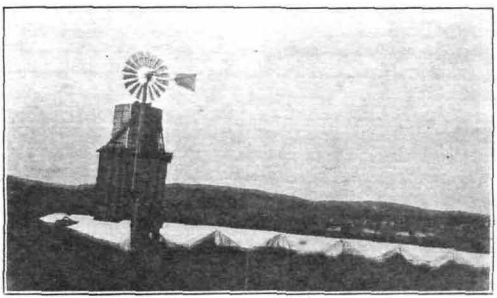

Fig. 1.—Canvas-covered cold-frames (6 × 60 ft.) into which the belladonna seed has been planted.

half inch, in rows three feet apart. The preparation of the soil and the seeding were continued as the rains and the soil conditions permitted. From January 18 to February 11 there was more or less rainfall every day and all field operations were discontinued during that period. By February 18 the seeding was completed.

A careful examination of the field some seven weeks later made it only too evident that the seedlings would not be able to force their way through the soil top-crust, and in the meantime weeds (mustard, California poppy, chickweed, bur clover, etc.) developed luxuriantly. In the entire area seeded not a thousand seedlings made their apearance, and arrangements were made at once to re-seed and re-till the entire field. This was done from February 19, to March 9. In addition three canvas-covered cold-frames (6×60 feet) were seeded on February 16 and 17, and March 3, about 1.5 pounds of foreign seed per frame being used.

As was half anticipated, based upon the complete failure of the first seeding, the second seeding did not yield much better results. A number of seedlings

made their appearance, but the prospects were so discouraging that the entire field was abandoned, excepting a small area of about one acre. This was cleared of weeds by hand labor, but even in this plat not one plant survived the summer drought.

About March 17 seedlings came up nicely in the canvas-covered cold-frames. By May 13 these were large enough for transplanting. About one acre was transplanted and irrigated (row or furrow method), but even with irrigation not over 25 per cent of the seedlings survived. In addition some three acres were planted, following the procedure of tomato transplanting, that is, the seedlings were put out in rows six feet apart each way. A small hole was dug, a quart of water poured into the hole thus made and mixed with dirt, into this the seedlings were planted. Not a single plant survived. It now became evident that belladonna seedlings were far less resistant to sunshine and

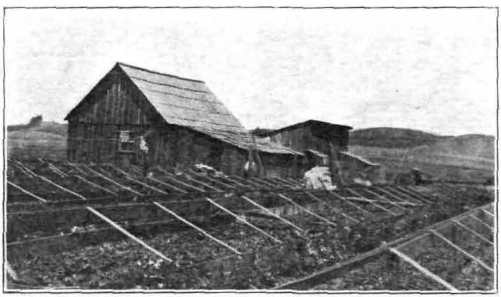

Fig. 2.—During the spring and summer the cold-frames are uncovered. Note that the beds are filled with seedlings.

drought that tomato seedlings. The young plants remaining in the cold-frames were kept free from weeds and occasionally irrigated. They made an excellent growth during the summer, most of them developing good roots.

The entire commercial experiment above outlined can be summarized as a complete failure, so complete, in fact, that if the writer had not had previous experience with belladonna culture he would have declared it a waste of time and money to make further attempts.

The reasons for the failure were as follows:

1. Unfavorable weather conditions. The season was chilly, rainfall deficient, dry winds and very little fog.

2. Slow germination of seed, the packing of the soil and top-crust formation, together with the slow growth of the seedlings make *field seeding wholly impracticable.*

3. The cold-frames were started too late. It was not intended to use cold-frames as it was hoped that field seeding would prove at least partially successful.

4. To the above causes must be added lack of experience, inability to secure dependable field labor, and also that the farm implements used were more or less unsuitable.

Based upon the experiences of the preceding year, the plan of procedure for the next year was as follows:

1. Begin operations in September or early October. Seed in cold-frames and begin transplanting in November.

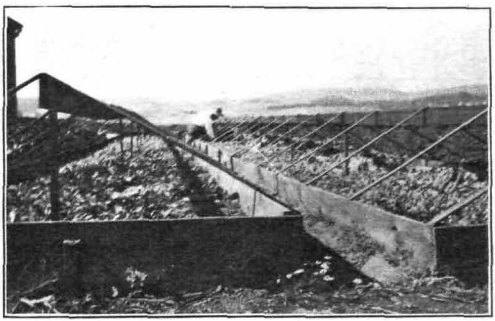

Fig. 3.—Open cold frames with belladonna seedlings. A laborer pulling out the weeds.

2. Time the cold-frame seeding so that transplanting may proceed in November, December, January and February. Transplanting to be completed by the first of March.

3. The field must be kept free from weeds by hand labor as well as by horse cultivation.

4. Seeding directly into the field was found to be impracticable and must be abandoned. The seed (in the field during the months of December, January and February) requires at least eight weeks to germinate. Within that period of time weeds grow and the field must be kept clear largely by hand labor, which is expensive. Furthermore, the tests of the previous year demonstrated conclusively that the seedlings cannot force their way through the soil top-crust.

5. Summer irrigation (June and July) to be tried.

6. Japanese labor to be employed by contract. Japanese day labor proved expensive and unsatisfactory.

From August 18 to October 18, 1908, sixteen cold-frames, each 6 × 60 feet, were prepared and seeded to belladonna. The time required for a goodly number of germs to appear varied from six to ten weeks and even longer. Cutworms killed most of the seedlings in several of the frames. During the winter months the young plants made very little growth. From December 9 to December 25 the weather was unusually cold for the San Francisco bay region, the temperature falling below 27 degrees F. on two or three occasions. Some of the leaves of the young plants were killed, but the roots remained in good condition.

On November 28 and 30, 1908, some of the plants from the cold-frames were transplanted (one acre), the soil being in excellent tilth. About February 28 three acres were transplanted, taking the larger plants from the sixteen cold-frames above mentioned. It soon became evident that these would not succeed in developing adequate root systems by the time the dry season set in. With special care perhaps 30 per cent would survive, but as this was not thought worth while the three acres were abandoned about March 22, thus leaving only the acre and a half of belladonna in the field. It was decided to leave the remaining seedlings in the cold-frames, caring for them properly, and transplanting in the succeeding November, by which time the roots would be well grown and hardy. The sixteen cold-frames now held about 200,000 thrifty plants, enough for twenty to twenty-five acres of belladonna for the season of 1910.

The belladonna in the field began to show buds in late January, 1909, and by May 15 the second year plants, transplanted May, 1908, were ready for the first harvest. In June the plants of one season's growth (transplanted November, 1908) were ready to cut. The yield was light, because of the unfavorable season, with little or no rain since the latter part of February. On July 15, 355 pounds net of perfectly dry and brittle belladonna were shipped to Johnson & Johnson. This represented the total yield of the first crop from one and a half acres. On July 22 the second crop was cut from the plants of two seasons' growth; the yield was somewhat better than the first; added to the first cutting it made a total yield of 800 pounds of dry leaves and stems from an acre and a half.

In all instances drying was done in the open. The leaves dried quickly, in three to four days, while the stems required from four to six weeks to become thoroughly dry. In this time some of the leaves were unavoidably lost.

The details of drying, packing and shipping had to be worked out. Drying in the sun and baling like hay was found to be, under the circumstances, most suitable for stems and leaves.

In the fall of 1913 the experimental efforts were transferred from the Castro Valley to San Leandro, near Oakland. About one-half acre of roots (crowns) was planted in the field and forty pounds of California-grown seed were seeded into large canvas-covered cold-frames. Through lack of care of the seed beds, not over one-sixth of this seed germinated, and more than half of the seedlings which made an appearance were allowed to die through neglect. In the fall of 1914 another half-acre of roots (one-year-old seedlings) was planted, and at the present writing there is in all about one acre of thrifty plants in the field.

Numerous experiments have been made with a view to hastening germination, but without marked success. Macerating for two hours in concentrated sulphuric acid shortened the period by several days. Macerating in water from one day to a week appeared to have no very marked effect. Soaking in boiling hot water for several minutes appeared to hasten germination somewhat.

AMERICAN EXPERIMENTS IN BELLADONNA CULTURE

The results of the experiments and tests in belladonna culture in the United States may be summed up as follows:

1. Belladonna can be grown on the Atlantic coast and on the Pacific Coast, and perhaps in every state of the Union.

Fig. 4.—Furrow irrigation. Japanese laborers transplanting seedlings.

2. In those states where the temperature falls below 10 degrees F. the roots must be taken up and protected against frost and again planted in the spring.

3. Because of the slow germination of the seed and the very slow initial growth of the seedlings, seeding must be done in hot-house frames in states with cold winter seasons, or in cold-frames where the winter temperature does not fall much below 30 degrees F.; transplanting to be done at the proper season and when roots are well grown.

4. Although a shade plant, it thrives well in the open in localities having cool nights and abundant fog (considerable atmospheric moisture). Seedlings require abundant soil moisture; when they are well rooted high soil moisture is not so essential.

5. *In the eastern states probably not more than one crop of leaves* and stems can be harvested in one season. Where the winter is not severe two and perhaps three crops can be gathered in one season.

6. The alkaloidal yield apparently runs high in belladonna grown in the United States, somewhat higher in California grown belladonna than in that grown in the eastern states.

7. Belladonna can be grown most profitably in the states having a mild winter climate for the following reasons:

(*a*) It is not necessary to take up the roots each year to protect them against freezing. This means a great saving in time and money.

(*b*) Growth begins (in California) about the middle of January. The first crop is ready for cutting about the first of June, the second crop about the middle or the latter part of July, and the third crop about the first of October.

(*c*) In California the absence of rain during the entire summer makes out-of-door drying possible, though drying by means of artificial heat gives better results.

CLIMATIC REQUIREMENTS

The immediate coast region from Washington to the lower part of southern California is well suited to the growing of belladonna. However, the results would not of necessity be the same in all parts of this long stretch of coast. It is possible too, that this plant can be grown successfully in the interior valleys of California with sufficient irrigation.

There are certain optimum climatic conditions required for the growing of a superior quality of this drug-plant considered from the standpoint of medicinal use and value. These requirements are as follows:

1. *Temperature and Sunlight.*—Belladonna is naturally a shade plant, establishing itself in rich forest lands and in other protected areas. It has also been made clear that the plant cannot survive the severe winters of the eastern and central states. Numerous tests have demonstrated that the plant thrives well in the open fields. Not only do the plants do well, but they show a very marked increase in alkaloidal content as compared with plants grown in shaded places. Extremely hot weather is harmful unless there is ample irrigation. Without such irrigation the leaves suffer from sunburn, resembling the sunburn of other herbaceous plants, such as sugar beets, potatoes, etc. A temperature which does not rise much above 80 degrees F.

is best for the growth of the plants, and is also conducive to a better yield of alkaloids.

Sunlight is even more important than temperature. All of the tests made have demonstrated that plants grown in the open freely exposed to the sunlight are richer in alkaloids than plants grown in the shade.

The reason why California grown belladonna is richer in total mydriatic alkaloids than that grown in the eastern United States is in all probability due to the fact that California has the greater number of clear days during the growing season.

2. *Rainfall.*—Belladonna requires considerable soil moisture to make a thrifty growth, therefore a comparatively heavy annual rain-

Fig. 5.—A view of belladonna plants in a field in Castro Valley near Haywards, California. The plants are of the third season.

fall is desirable. Good, rich, well-tilled soil receiving 20 to 30 inches of rain during the season (December to middle of March) will insure a good crop, other things being equal. In areas otherwise suitable where this amount of rainfall is not forthcoming, irrigation must be employed. Very heavy rainfall, again, has the effect of reducing the percentage of alkaloids, though the plants may make a very thrifty growth.

3. *Fog and Other Atmospheric Moisture.*—Belladonna thrives best in a region having sunny days and moisture-laden nights, conditions which exist in the immediate coast regions of California. With ample soil moisture (from rain or irrigation) and good tillage, the atmospheric moisture is not so essential.

SOIL REQUIREMENTS

1. *The Soil.*—The soil best suited to the growing of belladonna is *a rich, medium adobe and sedimentary loam. Excellent belladonna* has been grown in heavy black adobe when the latter was kept in good tilth. Good belladonna has also been grown in sandy soil well fertilized with stable manure. It will not do well in clayey soil.

2. *Drainage.*—There should be good sub-drainage and water must not be allowed to stand on the land. The plant requires considerable air, and considerable soil moisture, but it has no aquatic or marsh habits.

3. *Fertilizers.*—Belladonna is improved, in yield at least, through the use of fertilizers. Lime appears to increase the alkaloidal content and would be especially useful in the heavy soils and those tending to sour.

4. *Preparing the Soil.*—To insure a good crop the soil must be well prepared and if belladonna is to be successfully grown there must be no exception to this basic agricultural principle.

(*a*) *Plowing.*—Just as soon as the first rains of the season (November and December) have moistened the soil sufficiently, it should be plowed to a depth of at least nine inches. Every bit of the soil should be turned.

(*b*) *Discing.*—The plowed field is next gone over twice (crossed) with the familiar disc harrow, well overlapping each time. As this farm implement cannot be used in wet soil there is little danger of operating at the wrong time.

(*c*) *Harrowing.*—After the discing, the field should be harrowed twice, well overlapping each time, using a long-tooth harrow. The harrowing should be done just before the field is to be planted, in order to kill as many of the weeds as possible.

(*d*) *Marking.*—Mark off the field in cross lines three feet apart. This is, of course, done just before the transplanting. Other methods for checking the field for transplanting may be employed, but the marking (three to six rows) is the simplest. The tomato marker (six-foot rows) can be used by doubling the number of shoes.

SEED GERMINATION AND CARE OF SEEDLINGS

1. *The Seed.*—Seed may be obtained from England, France, Austria and Germany, through the larger New York seed firms. The price per pound is about twenty dollars. If possible, American-grown seed should be obtained, as this seed has a higher germinating power and

the seedlings are thriftier; also the alkaloidal yield is likely to be higher.

At the present time seed cannot be had from Europe, and the American supply is very limited.

The seeds are somewhat smaller than alfalfa seeds and brown in color. The seed coat is composed of suberized tissue which prevents the ready entrance and also the escape of moisture. The seed should be dry and kept in a dry place. Under such conditions it retains its germinating power undiminished for three and even four years.

2. *Preparing the Seed Beds, or Cold-Frames.*—For all parts of California adapted to the growing of belladonna, seeding is done in

Fig. 6.—The first load of belladonna from Castro Valley.

cold-frames. A suitable dimension per single bed is 6 feet wide by 60 feet long, and this should, if the work is properly done, contain enough seedlings for one acre of belladonna when planted in check rows three feet each way. For the sides of the cold-frames 10-foot boards twelve inches wide (third-class pine lumber will answer) may be used, breaking the joined ends on opposite sides, thus making it necessary to use one 5-foot piece at each end. Better sides can be made by using three 6-inch (fence) boards, making the total height 18 inches, the lower board being buried about three inches. The boards are nailed to and held in place by suitable stakes driven in (on the outside) at the corners and at suitable intervals along the sides. Along the middle of the bed stakes (1 × 4-in. × 3-ft. pieces) are driven for the support of the ridge pieces (1 × 4-in. × 12-ft.). This ridge piece is connected with the sides of the bed by laths nailed at intervals of three

feet. This roof frame is for the support of the canvas which is needed to keep out the winter rains, and also to protect the young seedlings against the occasional frosts.

Dig the soil out of the cold-frame to a depth of at least ten inches, put down a layer of well-rotted stable manure free from seeds of oats, barley, etc., and replace the soil on top of this layer of manure to a depth of eight inches. The manure warms the soil and hastens very materially the germination of the seed.

3. *Seeding into the Cold-frames.*—The soil in the beds being in proper tilth and suitably moist, scatter over the surface of the soil (broadcast by hand) 1.25 pounds of seed to each bed. Scatter the seed uniformly. Cover the seed by means of a rake, to a depth of about 0.25 inch, tamping the surface lightly, also by means of the rake. The soil must be fine and rich. If the soil is not rich it should be made so by adding leaf or other compost. A quart of lime mixed with the compost and soil of each bed gives good results. Mix this well into the upper third of the eight-inch layer of the soil in the bed.

The soil must be kept well moistened (not soggy or wet) up to the very surface all the time. *This is very important.* Seed lying near the surface in dry soil *will not germinate.* Irrigate by means of a garden hose or sprinkling can, using fine spray so as not to disturb the surface of the soil.

4. *Germination of the Seed.*—If the seeding is properly done in a properly prepared and cared-for bed or cold-frame, seedlings will begin to appear at the end of six weeks, and at the end of nine weeks nearly all seeds that are capable of germinating will have germinated. The two cotyledons which make their appearance resemble somewhat the cotyledons of the common chickweed. The seedlings make a slow growth.

5. *Care of the Seed Beds and the Seedlings.*—Even before the belladonna seeds begin to germinate it will be necessary to pick out weeds which have made their appearance. Early in the season up to July, the soil in the beds should be kept moist so that the seedlings may make a good growth and develop good roots. After July, the soil should be allowed to remain fairly dry, with just enough moisture to keep the plants alive. The weeds must be kept out at all times.

It is not necessary to transplant the seedlings into the open, as is done with tomato seedlings. This entails additional labor and expense which is probably not warranted by any gains which might result.

The cost of labor to make the frames, to seed them and to care for the seedlings in the cold-frame until ready for transplanting into the

Fig. 7.—A small patch of belladonna plants (first season's growth, from seed sown in January) in the back yard of a Salinas, Cal., home.

field, one year from time of seeding, is from $25.00 to $30.00 per frame for a group of ten to twenty frames (6 × 60 feet each).

For the coast region the best time for seeding is from the middle of December to the middle of February. Earlier seeding (September, October and November) offers no gain and the young seedlings are likely to be attacked by the cut-worm, which is active in October, November, and early December. Later seeding (March, April, and May) encounters the beginning of the dry season and compels daily or even twice daily irrigation to keep the surface of the soil amply moist, and the seedlings encounter the second, though lesser, ravages of the cut-worm.

The seed beds should be built in a protected place where winds and frost are least effective. The beds should have drain furrows to carry off the surface water, which might otherwise flood the cold-frames.

TRANSPLANTING THE SEEDLINGS

1. The season for transplanting the seedlings which have been cared for in the cold frames, is December, January, and early February, or just as soon after the first heavy rains as the soil can be properly prepared.

To transplant earlier than the time specified would be without gain, and as the first stem-buds begin to appear as early as the middle of February, transplanting should be completed somewhat earlier if possible. Plants may, however, be transplanted at any season of the year without killing them, if given proper care.

2. *Method of Transplanting.*—Take up the seedlings with a garden trowel or a small spade. Cut off the dead tops and leave about six inches of the main root, with such side rootlets as may be present. Place the trimmed seedlings in suitable trays or boxes (tomato boxes answer the purpose very well), and transport them to the field. A laborer throws the plants in or near the marked places and other laborers follow with short-handled hoes, such as are used in transplanting tomatoes, cutting a hole deep enough to receive root and crown, leaving only the dead stem remnant projecting above the surface of the soil. The crown part should be well covered, at least to a depth of one inch. Use fine dirt to cover the roots and crown, tamping in the loose soil with the flat of the hoe blade.

A light spade is also very convenient for making the holes for the plants, and while this tool offers certain advantages over the hoe, the energetic use of the latter gives better results. Japanese laborers invariably prefer the hoe.

TRANSPLANTING THE CROWN CUTTINGS

From what has already been said it is perhaps apparent that the grower uses seed once only, unless perhaps to furnish an increase in acreage over and above that which would result from the use of available crown cuttings.

1. *Preparing the Soil.*—The soil is prepared in the manner already described, by plowing, discing, harrowing and marking.

2. *Dividing the Crowns.*—The crowns are taken from the heeling-in bed and trimmed when necessary, the larger ones being cut into two, three, and even into five pieces. Some judgment will have to be exer-

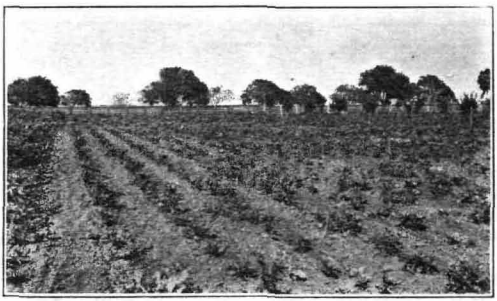

Fig. 8.—Belladonna field near San Leandro, Cal. The photograph was taken on the first of June. The field to the right contains plants which were transplanted (cold-frame seedlings) in February of the same year. The larger plants to the left represent second-year plants.

cised in dividing the crowns. Naturally, the larger the crown, the more likely it will be to develop into a thrifty plant. The number of visible buds is not the essential guide to the cutting process, as the crown parts bear many adventitious buds which may develop into stems. The smaller, single-rooted crowns are as a rule not divided. A large, sharp knife (butcher knife) should be used. A dull tool bruises and otherwise damages the crowns. The dead tops may be trimmed off and all badly bruised or diseased root portions removed.

3. *Planting the Crown Cuttings.*—The crown cuttings are dropped into convenient boxes and carried or otherwise transported to the field and planted much like the seedlings, as already described. Crown

planting is, however, simpler and easier. The holes need not be so deep, as the length of the crown cuttings does not exceed three or four inches, as a rule. The cuttings must be placed in vertical position and covered to a depth of three inches. In fact, the cuttings are planted much like potatoes. In this operation the short-handled hoe is by far the best implement to use.

It is absolutely necessary that the seedlings and the crowns be buried deep enough so that the soil-layer forming the covering is wholly below the general surface of the field level. Laying the crown on the surface of the soil and covering to a depth of three inches will not do, as the winter rains would soon wash the covering layer of soil away and expose the crowns, which would then fail to make a good start, or perhaps they would die altogether, as soon as the dry season sets in.

The larger roots (the tap root and the larger branches nearer the crown) are rich in adventitious buds, and as these buds will develop into shoots and stems, portions of the roots may be used for transplanting. However, as will be explained later, the roots are intended for the market rather than for transplanting.

CARE OF THE CROP

After the transplanting (of either seedlings or crowns) into the field is completed (from the latter part of January to early part of March) nothing further need be done until after the heavy winter rains have ceased. Just as soon as the soil is dry enough the field cultural operations should be started and kept up during the entire growing season.

1. *Cultivating.*—A two-horse, one-row cultivator should be used. Begin this operation as soon as the soil is in good condition for such work, even before the young shoots begin to make their appearance, being careful not to disturb the plants themselves. Cultivate in both directions (cross-cultivation).

The number of cultivations during the entire growing season (April to October) will depend somewhat upon the field (weeds) and the season. Certainly no less than five or six should be made. The soil should be kept in good tilth, which means that the top soil is to be fine and well stirred.

As soon as the plants are large enough (beginning of May) the dirt may be turned toward the plants more and more, care being taken that the smaller plants are not covered.

2. *Hoeing and Weeding.*—Cultivation will remove most of the weeds, but those which are close to the belladonna plants must be

removed by means of the hoe, aided by the hand. In all probability the field will have to be gone over in this manner three to four times during the growing season. Where indicated use the hoe to heap the dirt about the crowns.

3. *Irrigating.*—Irrigation is not essential in good rich soil with sub-soil seepage. Irrigating the first year is certainly beneficial and should be carried out, if possible, viz., once in April (latter part of the month) and just after the first crop is cut (latter part of May or early June). Row or furrow irrigation is best. Flooding is not good for the leaf development. Flooding is, however, feasible immediately after the first crop has been cut. Irrigation increases the root devel-

Fig. 9.—Belladonna field near San Leandro, Cal. The photograph was taken on the first of June. The plants are of the second year's growth, from crown cuttings.

opment so that as a result the second year's growth will give a somewhat larger yield also. Irrigation is, as a general rule, not required during the second, third and fourth years, as the deeply penetrating roots will secure ample moisture for stems and leaves. Irrigation does not increase the alkaloidal yield. It does increase the tonnage, however.

HARVESTING THE CROP

As already indicated, the herb (stems with leaves, flowers and some partially developed fruits) is cut at the time of maximum flowering, which for the first cutting is about the middle or latter part of May, or in a late season, in early June. The second crop is usually cut in late August.

1. *Harvesting the Herb.*—A small acreage (two to five acres) is generally cut by hand, using a large, heavy knife, or the pruning shears, taking two rows at one time. Make heaps of four rows. Do not make the heaps large, as this would interfere with drying.

In case of large acreage, ten to one hundred acres, a small self-rake reaper, cutting two rows at one time, would prove very valuable.

The larger basal parts of the stems should not be included, as they usually run low in alkaloids. Cut off the stems about four to six inches above the surface of the soil. In cutting by hand care should be observed not to include weeds which may be present. However, in a properly cultivated field weeds should be present in negligible quantities only.

2. *Cutting or Drying the Herb.*—In average California weather it takes from five to six weeks for the herb to dry, if left on the ground in the field. This long exposure to sun and more or less fog and night air moisture, causes a marked browning of stems and leaves, though there is apparently no great loss in active constituents. A better plan is to leave the plants in the field for five or six days and then to complete the drying in a hop kiln at a temperature of about 120 degrees F. This method will yield a better, greener and less broken article.

If the drying is done in the field the heaps should be turned several times each week. Do this in the morning before the leaves and small branches have become dry and brittle, so as to avoid loss. When drying is complete (all parts of the stems must be brittle), gather the material in the morning while damp into a wagon using a five-prong manure fork, and haul to the barn or place on a drying floor where it is allowed to remain for another week or two, preparatory to baling.

3. *Baling the Herb.*—When the herb is entirely dry it is pressed into bales of 100 to 125 pounds each by means of a hand-power hay press, or if large quantities are to be prepared for the market (50 to 100 tons) the usual horse-power hay press may be employed. Baling is best while the material is slightly damp, as in the early forenoon. The one who feeds the press should watch for and remove stray weeds and other foreign matter. The bales are wired like hay or straw bales, and when finished, placed in a suitable shed.

4. *Covering the Bales.*—The bales of belladonna are sewed into burlap for protection in handling in shipment and to keep out dust and dirt. Burlap suitable for the purpose can be procured wholesale for about four to six cents per pound.

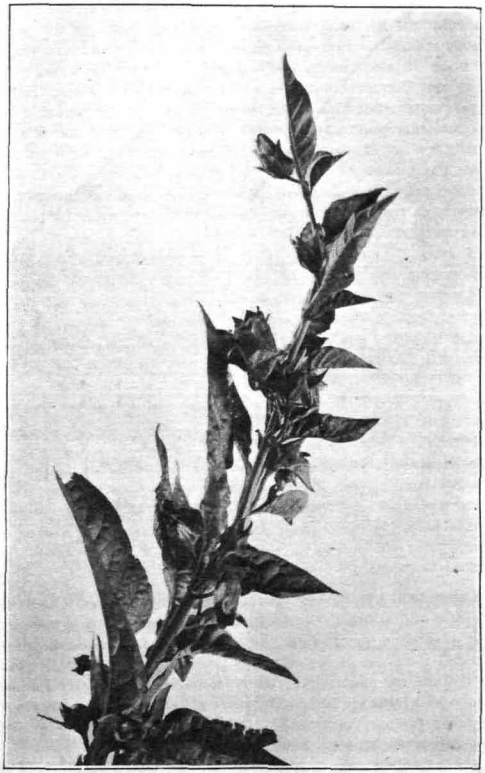

Fig. 10.—A single flowering branch of belladonna. An unexpanded flower is shown near the tip and two partially developed berries at the other end. Several fully expanded flowers are shown. Photograph taken June first.

5. *Harvesting the Roots.*—At the end of the fourth season immediately after the second crop of tops (herb) has been cut, the roots, with the crowns, are taken up. As the roots penetrate deeply into the soil a plow, such as is used for plowing up sugar beets, is required.

The roots are picked out of the soil carefully by hand, so as to avoid breaking them off in the lumps of soil, and placed in heaps. They are then thrown into a wagon and hauled to the drying place. By means of a large butcher knife or a beet knife, the crowns with about three inches of root are removed and the roots cut into lengths of four or five inches. The larger roots are also split in longitudinal direction once or twice, in order that they may dry more quickly. Washing the roots before drying is generally not necessary, as during this time of the year the soil is very dry and the roots are almost entirely freed from dirt by the handling. Should dirt cling to some of the roots it must be removed by means of a brush or whisk broom or by washing in water.

6. *Heeling-in the Crowns.*—Level an area of the field in some convenient place, removing dirt to the depth of several inches. Set in the crowns as closely as possible and cover with dirt to a depth of two inches. Here the crowns are to remain until the time for transplanting, that is, after the rains have set in and the soil is prepared to receive them. The heeled-in crowns must be irrigated slightly in order to keep them from drying out. Care must be observed that not too much water is used, as then they would start to grow, which is not desirable.

7. *Drying the Roots.*—The clean roots properly cut and sliced are spread on a board floor or on hurdles and dried in the sun, or in the kiln. If sun drying is to be carried out, the roots should be raked together each night and covered to keep out moisture. Sun drying will require from three to four weeks' time. Kiln drying at 120 degrees F. is preferable. Dried roots are packed and shipped in boxes or in sacks.

Roots and crowns are taken up once every four years. Four-year roots are apt to be somewhat woody and fibrous, and not of as high quality as third-year roots would be. However, it would hardly be advisable to take up the roots every third year for the sake of the slightly better quality and perhaps a correspondingly better price, because any such gain would be more than offset by the increased cost of preparing the soil and transplanting crowns every third year, which would have to be done as a consequence.

8. *Yield per Acre.*—As with other crops, the yield is variable. The first season's crop (two cuttings of the herb) should be 1800 pounds

net, dry weight. The second season's crop should be one ton and the third season should yield from 2100 to 2200 pounds dry weight. The

Fig. 11.—A single plant with one main stem, at time of flowering (April 22), from the belladonna farm at San Leandro. The plants are ready to cut (first seasonal crop). The second crop will be ready to cut in August.

fourth year should yield 2200 pounds of the herb and not less than 1000 pounds of roots, both dry weight. This would probably represent the maximum yield.

9. *Repreparing the Soil.*—As indicated in (8) the entire crop, roots and all, is taken up once every four years. This becomes necessary for several reasons. First, the plants become exhausted by the frequent cutting and require renewal; and second, the soil requires retilling. The soil is prepared in the manner already explained. Fertilizer (stable manure and lime) should be added. Lime is used, especially if the soil is of the heavy adobe variety. Manure is more especially required in the lighter, sandier soils. These matters have already been explained.

THE BELLADONNA MARKET

The demand for the dried herb, leaves and root is quite constant and is increasing slightly every year. The United States requires about three hundred tons of the drug annually. The European war has cut off the foreign supply almost completely, and the home production up to the present time is almost nil; as a result the price has risen from about twelve cents per pound to one dollar per pound at wholesale.

In addition to the demand for the drug in the dry state there is a very limited request for the green or fresh herb. In homeopathic practice the juice is expressed from the fresh plant and this, when mixed with an equal amount of alcohol, constitutes the "mother-tincture" from which the various attenuations (dilutions) are prepared.

1. *The Wholesale Market.*—The grower is interested in the wholesale market very largely. Any drug dealer or pharmaceutical manufacturing house that requires one or more tons of the drug each year may be considered a wholesaler. One American manufacturing house uses over eighty tons of the dried drug every year. Others use from nine to thirty tons per year. The grower should get in direct touch with the wholesale users of belladonna, instead of acting through a broker, agent or middleman. There is no excuse for a middleman.

Prospective buyers must be convinced of the quality of the article offered for sale, and they must be given some reasonable assurance as to the amount one may ship them from year to year. To convince them of quality, samples (about one pound of an average lot) must be submitted for chemical assay. For check purposes the grower should also assay a sample from the same lot. If the grower is not equipped for making an assay he should have done this for him by some competent and reliable pharmaceutical chemist.

3. *The Retail Market.*—The retail market for belladonna and other drugs, is represented by the drug stores of the land, of which there are many thousands. Each one of these stores carries a very small quantity of official belladonna (the dried root or the dried leaf, with terminal branches). The grower would have no trouble in finding a retail market for the root, but most practising pharmacists would probably object to the herb because of the large percentage of stems present. It would not be possible to market hand-picked leaves profitably for less than $1.00 per pound (the present war price is *nearly $3.00 per pound*).

Fig. 12.—A group of two plants from the same field as Fig. 11. These plants *and also the one shown in Fig 11, represent the third year's growth, first sea*sonal crop as explained under Fig. 11.

The American grower, for the time being at least, will not trouble *himself about the retail market. Later, when the market for the* home grown belladonna is fully established, the grower will also supply the retail pharmacist.

THE ALKALOIDAL YIELD OF BELLADONNA

The medicinal (therapeutic) value of belladonna depends upon the presence of certain active constituents, namely the alkaloids atropine and hyoscyanine and other so-called *mydriatic alkaloids, of which* atropine is the most important. The assays usually include the total amount of all alkaloids present. It will therefore be readily under-

stood that the commercial value of the drug depends upon the amount of alkaloids present. The variation in active constituents in the belladonna grown in different countries, and even in individual plants from the same field, is considerable. The alkaloidal yield is also greatly influenced by climatic conditions, sunlight, cultural methods and use of fertilizers, as has already been indicated. The first year plants (from seed) run low in alkaloids. The second year's growth runs much higher and the maximum alkaloidal yield is reached in the third year. The fourth year yield varies very little, if any, from that of the third year. The extremes in California grown belladonna thus far observed range from 0.12 per cent of total alkaloids in a first-year seedling which was grown in the shade, to 1.02 per cent in a single large fourth-year plant grown in rich sandy soil, freely exposed to the sun. The following are some of the alkaloidal yields of California field-grown belladonna.

Cold-frame seedlings (first-year growth) in open	
Total alkaloids	0.217 per cent
	0.358
	0.260
	0.304
	0.516
	0.423
	0.480
	0.224

Second and third-year plants (stems and leaves) in open	
Total alkaloids	0.775 per cent
	0.788
	0.590
	0.460
	0.784
	0.630
	0.675

Second and third-year plants (leaves) in open	
Total alkaloids	0.848 per cent
	0.822
	0.640
	0.500
	0.760
	0.720

Second and third-year plants (stems) in open	
Total alkaloids	0.852 per cent
	.0762
	0.590
	0.800
	0.684

Third and fourth-year plants (leaves) in shade	
Total alkaloids	0.474 per cent
	0.350
	0.238
	0.325
	0.442

Third and fourth-year plants (stems) in shade	
Total alkaloids	0.270 per cent
	0.400
	0.340
	0.425

Fourth-year plants (roots) in open	
Total alkaloids	0.540 per cent
	0.484
	0.500
	0.380

All of the tests thus far made indicate that the plants grown in the open, freely exposed to the sun, contain a much higher yield in alkaloids than do plants grown in the shade. The rather limited tests made indicate that lime is the only fertilizer that causes any marked increase in alkaloidal yield. This fertilizer is especially indicated in all heavier so-called adobe soils.

SUGGESTIONS RELATIVE TO THE INCREASE OF THE ALAKALOIDAL CONTENTS

The grower of belladonna should at all times endeavor to increase the quality of the drug. The chief effort should naturally be directed towards securing an increase in alkaloidal content. The importance of liming and free exposure to sunlight has already been mentioned. The following suggestions are based upon field observations, and it is believed that careful field tests along these lines will prove of great value in securing a further improvement in the quality of the drug.

1. *Cross-pollination.*—As already stated, belladonna should be harvested at the time of maximum flowering, because it has been found that at this time the leaves as well as the stems contain the seasonal maximum amount of alkaloids. The indications are that the alkaloidal content is proprotional to the number of flowers present; that is, comparatively numerous flowers indicate a comparatively high alkaloidal content. It would also appear that cross-fertilization increases the alkaloidal yield somewhat. It was noted that the yield was in every way better in a patch of belladonna grown near a large tomato field where there were numerous pollen-carrying insects, notably *Diabrotica 14 punctata*, and the brown lady bird, and also bees. Particularly noticeable was the increase in the yield of fruit (berries).

2. *Artificial Selection.*—The variation in the alkaloidal content of individual plants in the same field suggests that it might be easy to develop a stock rich in alkaloids by growing new plants from the crowns or from the seed of those plants which run unusually high in total alkaloids, following the methods which have proved so eminently successful in increasing the sugar content in sugar beets.

FIELD ENEMIES OF BELLADONNA

Fortunately the field enemies of belladonna are few, and none of them appear to work any great harm. The following are the more important ones thus far observed:

1. *The Army-worm or Cut-worm.*—The larvae of *Diabrotica 14 punctata*, commonly known as cut-worm, and which is frequently so destructive to tomato seedlings, may be destructive to the very young belladonna seedlings. The seasons for the greatest activity of the cut-worm are October and November, and again early spring (March

and April). The seeding of belladonna should be so timed as to avoid the periods of cut-worm activity, as has been suggested.

2. *Diabrotica.*—The beetle *Diabrotica 14 punctata*, commonly known as green-backed lady bird, may work harm by feeding upon the leaves. The harm done is in direct proportion to the amount of leaf tissue eaten, but at no time has the destruction by this insect been sufficient to materially lessen the yield.

3. *Root Rot.*—Seedlings (in the cold frames) and the roots of older plants (fourth and fifth-year plants) may be attacked by fungi, causing partial and even complete destruction of the plant. Plants thus killed in the field should be replaced by new well-rooted seedlings or crown cuttings.

4. *Aphis.*—A species of aphis has made its appearance upon some of the plants which were grown in the shade. None have thus far been found on sun-grown plants.

5. *Frosts.*—Late spring frosts may kill off some of the leaves of the young shoots. This is of rare occurrence along the coast, and the injury done is usually trivial.

6. *Sunburn of Leaves.*—During hot summer days some of the older basal leaves may be killed by the sun's rays. The injury done in this manner is also slight. A wilting and browning of basal leaves is usually an indication that it is time for cutting the crop.

7. *Squirrels and Gophers.*—These are common agricultural pests in California, but are no more destructive to belladonna than they are to other crops.