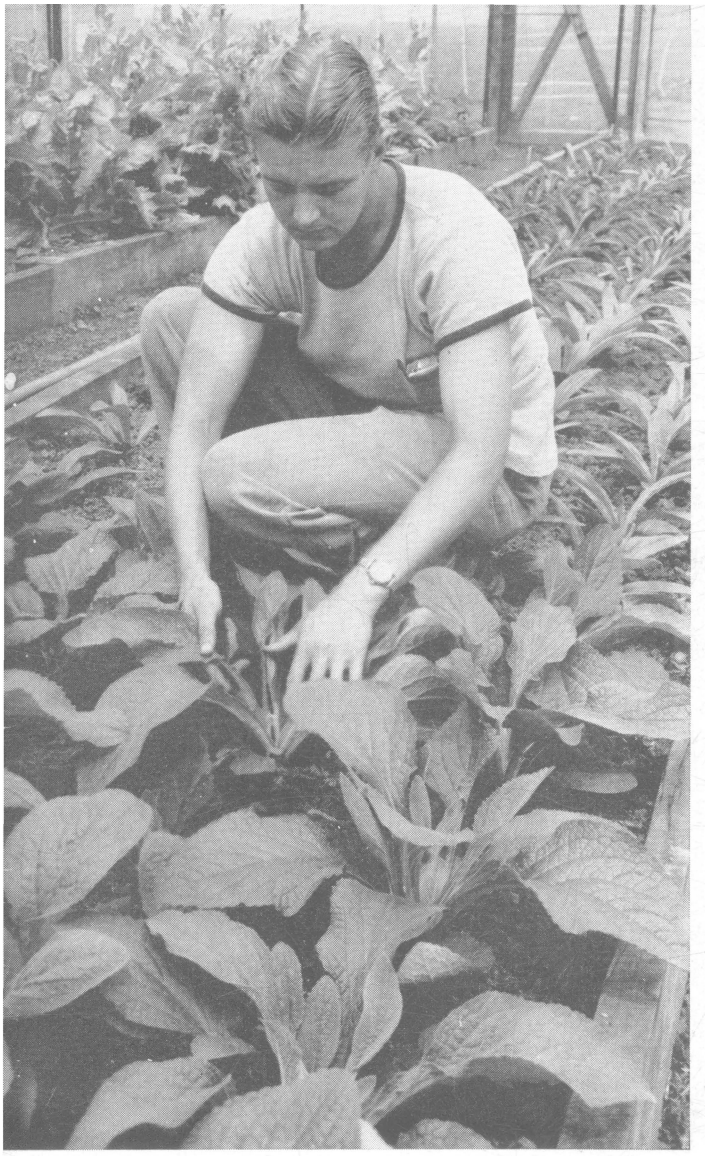

Digitalis purpurea growing in cloth house

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MEDICINAL PLANT CULTURE in Ohio

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Medicinal Plant Culture in Ohio

ALEX LAURIE, E. N. STILLINGS, AND W. R. BREWER[1]

INTRODUCTION

With the outbreak of hostilities throughout the world in 1941, the essential crude drug supply of the United States became quite imperiled. Total absence of imports drew heavily on the reserves established in this country during previous years. To increase depleted stocks of crude botanicals and to establish more efficient and practical procedures in lieu of the current empirical practices for production of these materials in this country, a federal cooperative project was established in January 1942, by the Department of Horticulture of the Ohio Agricultural Experiment Station, and the Colleges of Pharmacy and Veterinary Medicine of The Ohio State University. The prime objective of this project was to determine practical methods for production of these crops by growers in Ohio.

The initial studies included *Atropa belladonna* (deadly night shade), *Digitalis purpurea, D. lanata, D. lutea,* and *D. ambigua* (the foxgloves), *Hyocyamus niger, H. pictus, H. pallidus* (henbanes), *Datura stramonium* (jimson weed), *Carum carvi* (caraway), *Coriander sativum* (coriander), *Althea officinalis* (marshmallow root), *Plantago psyllium* (French psyllium), *P. ovata* (blond psyllium), *Pimpinella anisum* (anise), *Capsicum frutescens* (cayenne pepper), *Chrysanthemum cinerareaefolium* (pyrethrum flowers), *Chenopodium ambrosioides* (pigweed), and numerous plants belonging to the *Labiatae* (mint) family. Since the importance of many of these is limited, work was centered on a few, namely *Atropa belladonna* and *Digitalis purpurea.*

[1]The work herein described was made possible through the wholehearted cooperation of Dean B. V. Christiansen of the College of Pharmacy and the direction of Dr. L. D. Hiner of the College of Pharmacy, The Ohio State University.

REVIEW OF PREVIOUS EXPERIMENTAL WORK

Very little work of experimental nature was done with drug plants prior to the start of this project. A brief review follows:

Schneider (6) worked with *Atropa belladonna* in California from 1906 to 1910. His findings on culture were: (1) *A. belladonna* can be grown commercially in the United States, (2) roots must be taken up and stored when the temperature falls below 10° F., to avoid loss, (3) seedlings must be started indoors, (4) alkaloid yield is higher if soil is heavily limed, and (5) alkaloid yield is increased in crossbred plants.

Stockberger (8) states that *A. belladonna* can be grown from cuttings taken early in the spring, but it is more readily grown from seeds. A distance of 20 inches by 30 inches is advocated for planting in the field. He also states that the plant thrives best in a deep, moist, well-drained loam containing lime.

Reporting the general results of a federal *A. belladonna* project undertaken in the United States in 1942, Sievers (7) found the principal difficulties encountered were (1) loss of seedlings due to damping-off, (2) crop failure due to delayed transplantings to the field, and (3) flea beetle damage, especially affecting young plants. In some localities drying facilities were not adequate at first. Harvesting and drying required by far the most labor. Of the total 350,000 pounds produced in six states, Pennsylvania and Wisconsin accounted for two-thirds, while the four states, Tennessee, Kentucky, Ohio, and Virginia, produced the remainder.

From studies of the potency of *Digitalis,* Hepler *et al.* (4) found that the most favorable time for planting out in New Hampshire was June 1, the leaf blade contained more glucoside than the petiole, freezing of the plant material did not destroy the glucoside, and when dried above 200° F., the glucoside was destroyed.

EXPERIMENTAL STUDIES OF BELLADONNA

A. belladonna, the plant which proved most promising of all those investigated and one of the most critical at the time, is a bushy perennial herb native to Central and Southern Europe and Asia Minor. A member of the *Solanaceae* family, its dark green leaves are alternate, broadly ovate, and entire or nearly entire along the margin, and have an acute apex and tapered base. Secondary leaves are borne axillary to the main leaf along with the flowers which are usually solitary, rarely in clusters of two or three. The ripe fruit is a shiny black berry with a persistent calyx. Figure 1 shows *A. belladonna* growing in gravel culture in a greenhouse.

Fig. 1.—*A. belladonna* growing in greenhouse

Germination

The first lot of *A. belladonna* seed was sown on March 6, 1942. Germination occurred in 13 to 17 days and the seedlings were sufficiently large enough for pricking off in 25 to 30 days from time of sowing. All mediums used were steam sterilized. A temperature of 60° F. was maintained.

There were five mediums used: equal parts sand, silt loam, and German peat; equal parts sand and silt loam; equal parts sand and German peat; equal parts silt loam and sand with a covering of sphagnum moss; and German peat. Each medium was triplicated; one flat watered overhead, one flat subirrigated with one glass wick to a flat, and one flat subirrigated with two glass wicks to a flat.

The percentage of germination is shown in table 1. Germination was higher than previous reports had indicated, though there were no significant differences observed between treatments.

During the summer of 1942, seeds were collected from plants in Columbus, Ohio. The seeds were carefully separated according to time of collection, age of plants (seeds from 1- and 2-year-old plants were used), condition of fruit at collection, method of drying, condition after drying, and size of seed. The best germination occurred with seed from completely dried and mature fruits. From such fruits, were obtained large, well-filled, dark-colored, shiny seeds, while seeds from unripe fruits gave a low percentage of germination. Cutting tests indicated that dark embryos and endosperms are not objectionable and have little effect on viability.

TABLE 1.—Belladonna seed germination forcing test

Treatment	Germination (Percent)
Check	25
45° F., 2 weeks	29
45° F., 5 weeks	47
70° F., 1 week; 45° F., 1 week	13
70° F., 1 week; 45° F., 2 weeks	21
70° F., 1 week; 45° F., 3 weeks	29
70° F., 1 week; 45° F., 4 weeks	31
70° F., 2 weeks; 45° F., 1 week	17
70° F., 2 weeks; 45° F., 2 weeks	4
70° F., 2 weeks; 45° F., 3 weeks	9
70° F., 3 weeks; 45° F., 1 week	10
70° F., 3 weeks; 45° F., 2 weeks	29
Sulfuric acid ½ minute	27
Sulfuric acid 1 minute	52
Sulfuric acid 2 minutes	30
Sulfuric acid 5 minutes	20
Sulfuric acid 10 minutes	7
Sulfuric acid 15 minutes	4
Water 7 days, 50° F.	35
Water 7 days, 60° F.	50
Soil 60° F., 7 days	55
Moist burlap, 90° F., 7 days	65
Moist soil, 90° F., 7 days	89
Water 24 hours, moist soil 90° F., 7 days	92
Moist soil 90° F., 7 days, glass cover	95
70 percent sulfuric acid 1 minute, water 24 hours, moist soil 90° F., 7 days, glass cover	98

Early results from this second germination study indicated that special treatments were needed to increase the percentage as well as the speed of germination. With this end in mind, further studies in germination were undertaken.

The treatments consisted of soaking in water for 7 and 10 days, soaking in 70 percent sulfuric acid, storing at different temperatures for varying lengths of time, planting in soil at different temperatures, and covering flats with glass. All seeds were sown in a light loam soil which had been steam sterilized. Table 1 shows the germination percentages of nine different samples carried through each of 26 treatments.

Mediums which dry out readily should be covered by glass to retain moisture about the seeds. For such a constant condition, subirrigation of the seed flats is desirable.

It can be noted in table 1 that cooling after planting resulted in poorer germination than the check lot in all but three cases. Treatments with commercial strength sulfuric acid proved better than the checks in some cases. The lots germinated in high temperature were most satisfactory. Covering the flat with a pane of glass increased the humidity above the medium and resulted in a higher percentage of germination. Combinations of high temperature and uniform high humidity are of greatest importance in germination of *A. belladonna* seed.

The recommended treatment based on this study would be to immerse the seeds in commercial strength sulfuric acid for 60 to 100 seconds, soak in water 24 hours, and then sow in a sandy medium where the medium temperature can be maintained at 90° F. for 1 week, then reduced to 60° F.

Propagation Study

As soon as the majority of the seedlings had produced a pair of true leaves, they were pricked off.

During the spring of 1942, some *A. belladonna* seedlings were pricked off into flats, spaced 2 inches by 2 inches in the flat; some were pricked off into 2½-inch pots; and some were pricked off into 2-inch wooden plant bands. These variations were established to determine the most desirable type plant for setting out in the field.

The first planting out was done the second week of May. Those plants which were contained in wooden bands were stripped of the bands before planting. There was no significant difference in production or observable difference in growth in this planting.

The pot and plant band treatments were more favorable than the flat treatment in late May and early June planting in that they made possible more rapid establishment of the plants resulting in better growth during the warm dry weeks which followed.

By placing the young plants in a cold frame for 5 to 6 days prior to planting and thus hardening them off, it is possible to plant in the field late in April or early in May, depending upon locality. Light frosts will not damage them. For high production, early planting is essential.

Plants should not be set deeper in the field than they were in the original flats or containers, or stem rot may develop.

Spacing Tests

Table 2 shows the comparative production of plants spaced 12 inches by 12 inches and those spaced 24 inches by 24 inches.

TABLE 2.—Belladonna production spacing test

Spacing	Grams per plant	Pounds per acre
Spaced 12 × 12 inches	63.4	6,086
Spaced 2 × 2 feet	61.3	1,473

*Dried and ready for assays. Unless specified otherwise, production figures are based on leaves and small stems (10 mm in diameter or less).

Both treatments produced nearly the same amount of material per plant, but by having four times as many plants per acre with the close spacing the production per acre is quadrupled.

The close spacing is practical only for small plantings and when hand labor is to be used for planting, dusting, and cultivating; it cannot be used when power or horse-drawn equipment is to be employed. Plants in the row can be set as close as 12 inches, while the distance between rows will depend on the tools used. Twelve inches between plants and 30 inches between rows is suggested as a practical spacing. For such a planting, 17 thousand plants per acre will be required. A spacing of 12 by 12 inches, leaving every seventh row unplanted, will provide aisles through which all parts of the planting are accessible for all operations. Such a spacing will require 37,180 plants per acre.

Light Studies

To determine the most satisfactory light intensity which would produce optimum vegetative growth and the highest alkaloid content within

the plant material, *A. belladonna* plants were grown under aster cloth, in a lath house, and outside without protection. The production yields obtained and assays of the material from these plots are shown in table 3.

TABLE 3.—Production of belladonna under varying light conditions

Treatment	Grams per plant	Pounds per acre	Assays, percent alkaloid
Normal (6,000 foot-candles)	63.4	6,086	0.33
Cloth house (4,000 foot-candles)	57.1	5,481	.22
Lath house (3,500 foot-candles)	26.5	2,544	.23

It is evident that reduction of light intensity is detrimental to total dry weight and alkaloid synthesis. The material from the cloth house was bulky and quite succulent, hence the yield of dried material was much reduced. Plants in the lath house were very succulent and leggy.

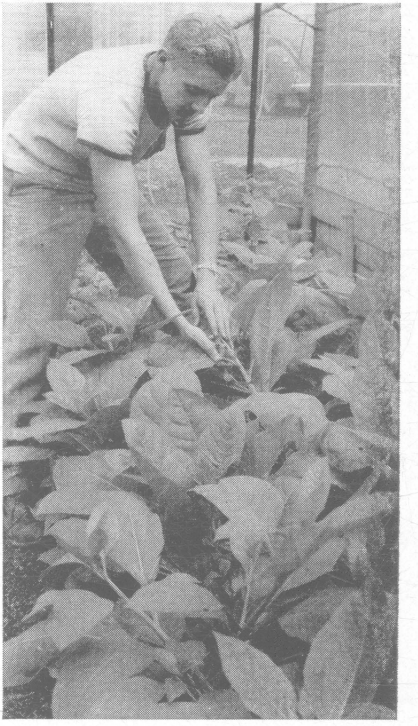

Fig. 2.—*A. belladonna* growing under aster cloth. (35 percent reduction in light.)

Nutrition

To determine the nutritional requirements of *A. belladonna,* eight different nutrition levels, with varying concentrations of nitrogen, phosphorus, and potassium, were established. Each variation was used in soil with a pH of 6.5 to 7.5 and 5.5 to 6.5. The concentrations of available nutrients for the plots were: high nitrogen,[2] 50-100 parts per million; low nitrogen, 10-50 parts per million; high potassium, 20-40 parts per million; low potassium, 5-20 parts per million; high phosphorus, 5-10 parts per million; and low phosphorus, 1-3 parts per million.

[2]Difficulty in maintaining accurate levels made elimination of *medium* levels necessary.

These soils were tested every 10 days, and the needed elements added. The plots which were set up for low concentrations were carried at or below the middle of the range indicated. Those which contained high concentrations were maintained in the lower half of the range indicated with the exception of potassium. Because of the nature of the soil and frequent rains, it was impossible to maintain a high level of this element. Therefore, frequent applications of this element were made to the high potassium plots.

The first year of this test (1942) 18 plots were used, one for each treatment. Three harvests were obtained from these plots. In 1943, to confirm the findings of the previous year, the same study was made, each plot being replicated four times. There were four harvests from the second-year plants and three harvests from the first-year plants. The crops were cured on racks in a dry, well-ventilated, darkened room. Dry weights were obtained for calculations of production yields and the material was ground and assayed for determination of alkaloid contents. Production figures for the 1942 and 1943 crops appear in table 4.

TABLE 4.—Belladonna production in soils with variations in available nitrogen, phosphorus, and potassium and soil pH

Treatment†	pH	Pounds per acre* 1942	1943	1943—2 years old
High NPK	6.5-7.5	5,981	4,118	10,666
	5.5-6.5	5,712	3,523	12,364
Low N, High PK	6.5-7.5	5,203	2,313	8,976
	5.5-6.5	4,800	1,747	9,840
Low NP, High K	6.5-7.5	3,532	2,266	9,980
	5.5-6.5	4,041	2,150	2,150
High N, Low PK	6.5-7.5	3,897	1,987	9,485
	5.5-6.5	6,700	2,755	14,582
Low NPK	6.5-7.5	3,312	2,237	7,065
	5.5-6.5	3,254	2,803	7,622
High NK, Low P	6.5-7.5	4,473	2,986	9,466
	5.5-6.5	4,665	3,850	10,685
Low NK, High P	6.5-7.5	2,918	2,467	6,720
	5.5-6.5	4,406	1,939	9,561
High NP, Low K	6.5-7.5	6,038	2,918	19,267
	5.5-6.5	5,366	3,110	10,214
Control	———	4,740	2,496	7,066

*Dry weight. Plants spaced 12 inches by 12 inches.
†High N, 50-100 p p m; P, 5-10 p p m; K, 20-40 p p m.
Low N, 10- 50 p p m; P, 2- 5 p p m; K, 10-20 p p m.

By adding together all yields in the same column from plots which had high concentrations of available nitrogen and likewise adding all

yields in the same column from plots which had low concentrations of available nitrogen, the treatments can be correlated. The production figures and alkaloid assays for these comparisons appear in table 5. All assay figures are in percentage of alkaloids as determined by the United States Pharmacopoeia Assay. The material must contain .30 percent total alkaloids to be classified as official U. S. P.

TABLE 5.—Belladonna production and assays for 1942 and 1943 (table for nutrition and pH variation)

	High nitrogen		Low nitrogen		High phosphorus	
	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old
Pounds per acre	4,211	12,091	3,068	8,439	3,909	10,951
Assay (percent)	.38	.37	.40	.36	.38	.38
	Low phosphorus		**High potassium**		**Low potassium**	
	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old
Pounds per acre	3,432	9,579	3,835	9,966	3,506	10,562
Assay (percent)	.40	.36	.39	.36	.40	.38
	pH 6.5-7.5		**pH 5.5-6.5**		**Control**	
	1-year-old	2-year-old	1-year-old	2-year-old	1-year-old	2-year-old
Pounds per acre	3,792	10,067	4,061	10,461	3,618	7,066
Assay (percent)	.39	.38	.43	.38	.34	.44

In both years high soil nitrogen levels resulted in greater weight production over low nitrogen. Lack of uniformity in results of potassium studies over the 2 years, combined with the fact that small infrequent applications produced yields in excess of the control plot, indicates that only a low level of this element is sufficient for optimum production. These results may be seen more clearly in a composite of the 2 years' results as shown in table 6. The low pH plots produced higher yields for both years, as did the high phosphorus plots.

The increase of alkaloids in the plants from the low pH plots is interesting in that all recommendations for growing *A. belladonna* specify the necessity of heavy applications of lime.

Leaf material from the first harvest assayed higher than did the other samples of leaves and flowering tops.

TABLE 6.—Composite of production and assays for 1942 and 1943 (correlation table for nutrition and pH variations)

	High nitrogen	Low nitrogen	High phosphorus	Low phosphorus
Pounds	6,838	4,871	6,257	5,481
Alkaloids (percent)	.38	.39	.38	.39
	High potassium	**Low potassium**	**pH 7**	**pH 6**
Pounds	5,878	5,859	5,883	6,197
Alkaloids (percent)	.38	.39	.39	.41

Nutrient study plots were established in the greenhouse the first week of June, 1942. These consisted of gravel culture plots in which the plants were grown in an inert medium with the essential nutrition supplied by regular pumpings of water containing the dissolved nutrient salts. By this procedure, the concentrations of essential elements were more easily controlled than in soil culture. Variations of nitrogen, phosphorus, and potassium were again used, but this time there were three variations of each element rather than two. The greenhouse used was difficult to ventilate properly and was very hot during the middle of the summer—adequate means for maintaining a high humidity were lacking. As a result, the growth of plants was unsatisfactory.

With three variations of the elements, it was necessary to compare plots treated with but two variations. All those containing low and medium concentrations and medium and high concentrations were figured together. In table 7 it will be noted that high concentrations of available nitrogen and available phosphorus increased the yield. Medium potassium yielded higher than both low potassium and high potassium. This result was not surprising, as the increase from high potassium in the outside plot was not significant.

From these nutrition tests it is evident that if the soil does not already test high in available elements, fertilization is necessary for high yields. The application of fertilizer will be partially governed by the quality of material to be produced, as shown by the assay table. Since higher prices are not paid for superior quality (assaying extremely high), it should be the aim of every grower to produce as much material of standard quality as possible. This cannot be done without fertilizers.

Before planting, 20 percent superphosphate should be well worked into the soil at the rate of 400 pounds per acre. Ten days to two weeks after setting out in the field, growth should have started, and a side

TABLE 7.—Belladonna production (table for gravel culture nutrition study)

Treatment	Grams per plant	Pounds per acre
Low N	27.4	2,630
Medium N	58.1	5,577
Medium N	57.9	5,558
High N	71.7	6,883
Low P	37.6	3,609
Medium P	47.9	4,598
Medium P	71.7	6,883
High P	57.9	5,558
Low K	38.0	3,648
Medium K	47.5	4,560
Medium K	64.5	6,192
High K	65.1	6,249

Low—¼ WP; medium—1 WP; high—2 WP.

For constituents of these solutions see Kiplinger, D. C., and Alex Laurie. 1942. Growing ornamental greenhouse crops in gravel culture. Ohio Agr. Exp. Sta. Bull. 634.

dressing of a complete fertilizer (3-8-7 will prove satisfactory) at the rate of 500 pounds per acre should be made. A similar application should follow the first and second harvests.

Time of Fertilizer Application

In view of the increase in nitrogenous constituents of certain field crops upon the additions of fertilizers at late stages of growth rather than at early stages, *A. belladonna* plots were enriched with ammonium sulfate at the rate of 4 pounds per 100 square feet at three stages of development (pre-flowering, flowering, and fruiting) in an attempt to increase the alkaloidal content. The comparison of alkaloid yields of these plants with a check plot is presented in table 8.

TABLE 8.—Belladonna assays of whole plants grown in plots nitrated at three states of growth

Treatment	Alkaloid assays
	Pct.
Check plots	0.31
Soil nitrated at pre-flowering stage	.37
Soil nitrated at flowering stage	.22
Soil nitrated at fruiting stage	.30

These data indicate that *A. belladonna* plots should be fertilized soon after establishement of the plants.

Greenhouse Versus Outdoor Culture

Since at the time, curtailment of flower crops was considered possible, it was deemed worthwhile to learn whether *A. belladonna* could be grown successfully in the greenhouse.

On May 15, 1942, *A. belladonna* was planted in a raised bench of soil in the greenhouse, to be grown under conditions of high temperature (60-85° F. at night) and high humidity (65-80 percent). The comparative yields are given in table 9.

TABLE 9.—Production of belladonna—greenhouse versus outdoors

Date of harvests	Pounds per acre*	
	Greenhouse	Outdoors
June 15	904	
July 6		1,276
July 21	880	
August 5		1,565
August 18	528	
September 1		1,382
September 7	880	
October 12	872	1,862
Totals	4,064	6,085

*Spaced 12 inches by 12 inches, both outdoors and in the greenhouse.

Although the greenhouse plots produced one more harvest than did the outdoor plots during the same period of time, the outdoor plots produced more material.

The plants grown inside became dormant in November, and all visible growth ceased. They were almost at the harvesting stage at that time.

On the basis of what has been harvested, 29 pounds of dry material could be produced on a bench 100 feet by 42 inches, roughly 350 square feet of greenhouse space, in 1 year. An approximate cost of $1.00 per square foot per year for bench space and labor made the cost per pound about $3.00. The returns were about $1.00 per pound, which showed that *A. belladonna* could not be grown profitably indoors.

Colchicine Applications

Previous work with Digitalis indicated that the glucocide content could be increased, presumably by producing doubling of chromosomes. To test this theory, in 1942 a series of *A. belladonna* seedlings were treated with colchicine by immersion in solutions of various concentrations for various periods of time, or by applying 1 percent lanolin paste

or a 1 percent spray to the growing tips. These plants were carried through the season, seeds collected, and the seeds planted in 1943. The production of the 1943 plants appears in table 10.

TABLE 10.—Production and assays of plants grown from seeds collected from colchicine-treated mother plants

Treatment	Production	Assays
	Pounds	*Percent*
Seedling immersion, 0.3 percent solution 6 hours	1,359	0.46
Seedling immersion, 0.3 percent solution 4 hours	1,032	.36
Seedling immersion, 0.2 percent solution 4 hours	1,515	.34
On growing tips, 1 percent lanolin paste	1,302	.27
On growing tips, 1 percent aqueous spray	1,630	.43
Check plots	2,126	.44

One year's trials indicate little effect of colchicine on percentage of alkaloids and show a definite decrease in yield.

Plant Hardening Prior to Planting

When seedling plants are held in the greenhouse for a long period of time prior to planting, they often become spindly and weak. To determine the results in production of these weakened plants as compared with plants hardened before planting, some were pinched back at the growing tips and grown in cooler greenhouses. Table 11 indicates that the hardening of plants accustoms them to the climatic conditions of early planting.

TABLE 11.—Belladonna production after varied pre-planting treatments

Treatment	Temperature	Grams per plant	Pounds per acre
	(Degrees F.)		
Greenhouse check (no hardening)	65	25.9	2,126
Pinched back in greenhouse	65	24.9	2,044
Pinched back in cold frame	45	38.2	3,142

Hardening of plants prior to planting is conducive to quicker establishment in the field and greater yield.

The growth check resulting from pinching back is productive of a high carbohydrate reserve which in turn allows a rapid regeneration of new roots at the time of transplanting. Pinching back in the greenhouse

provides a temporary check in growth resulting in accumulation of carbohydrates, but the effect is lost since the carbohydrate reserve is soon reduced at the greenhouse temperature.

Harvesting

In 1942, material was collected when the plants were in flower and before formation of the fruit. If fruit is allowed to form, it will increase the time necessary for drying. Likewise, if the plant becomes mature, the next crop will take longer to develop, as the lateral buds will not develop as quickly as they should.

The first harvests were made by cutting the stems 8 to 10 inches above the soil level. It soon developed that more material could be cut without endangering the continued growth of the plant. Accordingly, the stems were cut to within 6-8 inches of the soil level. This practice reduced the number of harvests per season yet did not affect the total yield. There was sufficient foliage left on the plant to insure continued growth.

Too early application of water following harvesting caused a loss of numerous plants through root rot in a plot in the greenhouse. It was necessary to "dry off" the plants thoroughly before forcing growth. This procedure was practiced outdoors wherever irrigation of any form was used.

Time of Harvest

As no previous work showed a basis for harvesting *A. belladonna* at any particular time, in 1942 an investigation was carried out to determine the stage of development at which the highest alkaloidal yields could be expected. Results of this study appear in table 12.

TABLE 12.—Belladonna assays of plants harvested at three different stages of development

Time of harvest	Alkaloid yield (percent)
Harvest at pre-flowering	0.31
Harvest at flowering time	.34
Harvest at fruiting time	.29

From this composite of assays, it is apparent that the highest yield of alkaloids may be expected when the harvest is carried on during the flowering period.

Drying

Drying of the harvested material was first done by stripping the leaves from the stems and placing the material on 3-foot-square cloth-bottomed trays which fitted into racks. The trays were 4 inches apart in the racks to allow sufficient ventilation for both sides of the material. These racks and trays were located in a dry, well-ventilated building. From this method, developed a less laborious procedure. Nails were driven through the thin width of wooden strips (10 feet × 1 inch × 2 inches) in alternate directions at intervals of 4 inches. The stems were then stuck on these nails, and the racks hung up to dry. After the material had dried, the leaves were stripped and saved and the stems discarded. After some stem material had been assayed and found to contain a satisfactory amount of alkaloids, stripping of the leaves from the stems was discontinued.

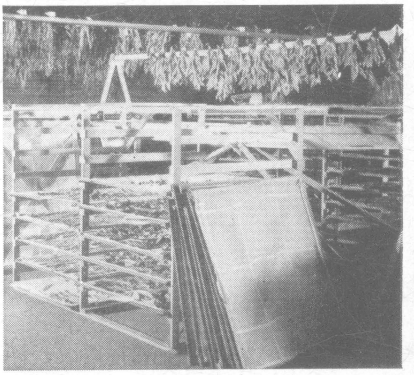

Fig. 3.—*A. belladonna* drying on racks. (Trays contain other drugs.)

The length of time required for drying varied with each harvest, depending on weather conditions. Seldom was it more than 3 weeks.

To determine whether there was any movement of the alkaloids within the stems and leaves after the material was harvested, a large lot was divided into three samples: Leaves and stems separated and dried on trays; leaves and stems separated after having been hung and dried on rack; and material hung on rack and dried, left intact. Both material produced in the greenhouse and material produced outdoors were tested. Table 13 shows the assays of these materials.

TABLE 13.—Belladonna assays—Drying test

Treatment	Material	Percent alkaloids	
		Greenhouse	Outdoors
Leaves and stems separated and dried on trays	Leaves	0.32	0.34
	Stems	.50	.53
Dried hanging, leaves and stems separated after drying	Leaves	.41	.38
	Stems	.45	.26
Dried on rack	Leaves and Stems	.52	.36

When the material was hung up to dry, the leaves contained more alkaloids than the stems, whereas when the material was spread out on trays, the reverse was true. This result suggests translocation of the alkaloids after the material is harvested.

Alkaloid Location

In harvesting *A. belladonna,* a cut is made about 6 or 8 inches above the ground, leaving several leaves intact to carry the plants through the next period of growth to subsequent harvest. As the plants begin to develop again, these leaves frequently attain the size of a man's hand and are conspicuous among the small leaves and growing tips. To determine whether the large or small leaves are higher in alkaloid content, a number of plants in different locations and at different ages were stripped of both types of foliage. The averages of all these assays for the two types was 0.266 percent for old mature leaves, and 0.381 percent for young leaves and tips; indicating that immature foliage has a greater alkaloid content.

Post-harvest Alkaloid Relocation

For many years, herbalists and herbal publications have advocated the curing of medicinal plants by suspending them in dry sheds from cords tied around the stems or roots. In the 1942 studies, *A. belladonna* plants were cured at first by separating the fresh leaves from the stems and curing the two parts on trays. Later, due to shortage of labor, plants were cut near their bases and the entire plants impaled on nails driven through long racks. In this way, the plants were cured hanging upside down and the leaves were stripped from the stems after drying. When the assays of the materials obtained by these various methods of harvesting were compared, an indication was found that when whole plants were hung up to cure there was a passage of alkaloids from the stems into the leaves. In order to confirm these results, further tests were made in 1943. Plant material collected from 2-year-old plants in 1942 was assayed, with the results shown in tables 14 and 15.

TABLE 14.—Post-harvest alkaloid relocation in 2-year-old plants

Treatment	Percent of alkaloids	
	Stems	Leaves
Leaves and stems separated and cured on trays	52	48
Whole plants cured on racks before separation	48	52

TABLE 15.—Post-harvest alkaloid relocation in 1-year-old plants cured with roots intact

Treatment	Percent of alkaloids		
	Roots	Stems	Leaves
Plant parts separated and cured on trays	50	16	34
Whole plants cured on racks before separation	47	17	36

Since the roots of *A. belladonna* have been known to contain more alkaloids than other portions of the plant, it was thought that this high content could be transferred to the leaves by hanging the whole plant, including roots, from racks as indicated. Consequently, plots of *A. belladonna* were harvested and the plants cured by the two methods previously described (see table 16).

TABLE 16.—Post-harvest alkaloid relocation in plants of varying stages of development

Development stage of plants	Material	Parts cured separately	Whole plant cured before separation
		Percent alkaloid	*Percent alkaloid*
Pre-flowering	Stems	55	57
	Leaves	45	43
Flowering	Stems	54	51
	Leaves	46	49
Fruiting	Stems	51	43
	Leaves	49	57

Considering the data presented in table 16, it appears that the post-harvest mobility of alkaloids increases with the age of the plants.

Two explanations seemed possible for the phenomenon of alkaloid relocation in plants hanging upside down; (1) that some physiological process was tending to draw the alkaloids down into the leaves, and (2) that the movement was an effect of gravity. To determine the validity of this latter explanation, plants were cured while being maintained in an upright position. If the effect were due to gravity, the alkaloids should have moved into the roots. The results appear in table 17.

To positively establish alkaloid movement, a special test was devised utilizing only one set of plants and thereby eliminating the confusing factor of natural variation in alkaloidal content of different sets of plants. One-half the leaves of a group of plants was stripped off while fresh and cured on trays, while the other half was left on to cure on the plants,

hanging from racks. The assays of these two sets of leaves showed 0.27 percent alkaloids from leaves cured on trays and 0.39 percent from plants hanging from racks.

TABLE 17.—Post-harvest alkaloid relocation in plants cured in an upright position

Treatment	Percent of alkaloids		
	Roots	Stems	Leaves
Plants cured separately on trays	0.50	0.16	0.34
Whole plants cured upright before separation	.35	.22	.43

When mature plants are cured whole, regardless of upright or inverted position, the quantity of alkaloids in the roots is diminished and the quantity in the foliage is increased. If the roots are removed, the alkaloid ordinarily present in the stems is shifted to the leaves.

Mulching

With the thought that it was desirable to carry plants through the winter in order to take advantage of the higher alkaloid yields of 2- and 3-year-old specimens, heavy, medium, and light mulches were applied to light loam and heavy soil plots in December of 1942. In the spring of 1943, these plots were checked for survival. The results appear in table 18.

TABLE 18.—Mulching and winter survival of belladonna plants

Amount of mulch	Percent survival
Silt loam plots	
Heavy mulch— (12 inches strawy manure)	75
Medium mulch— (6 to 8 inches strawy manure)	60
Light mulch— (3 to 4 inches strawy manure)	57
No mulch	9

Amount of mulch	Survival
Heavy soil plots	
Heavy mulch	Heavy losses
Medium mulch	Best results
No mulch	Heavy losses

Comparison of the winter survivals of equally mulched plots maintained under varying nutritional levels showed 64 percent survival from high nitrogen plots and 84 percent from low nitrogen plots. It appears that reduction of the nitrogen level of the soil toward the end of the growing season is conducive to greater winter survival. Variations found with other elements were insignificant.

Insect Control

Although no initial studies were set up to cover this phase of *A. belladonna* culture, much was learned regarding the damage done by insects, their occurrence, and their control. The first pest to appear was the greenhouse slug, which destroyed some seedlings before time for planting out. Damage could have been severe, but the insect was easily controlled by placing an arsenical bait in the vicinity of the seedlings. A leaf miner, believed to be the spinach leaf miner, appeared in plants in the greenhouse and caused severe damage. After transplanting, injury was less noticeable, and by the end of June there was no trouble from that source. Control of this insect in the greenhouse was best accomplished by spraying with nicotine sulfate 1 to 200.

Insects appearing on the plants outdoors were numerous. Colorado potato beetle, striped and spotted cucumber beetles, blister beetle, tortoise beetle, flea beetle, and leaf skeletonizers were the most serious pests. Since all these insects have chewing mouth parts, a stomach poison will control them. A dust composed of 85 parts of sulfur and 15 parts arsenate of lead will prove satisfactory providing good coverage of foliage is secured. No control measures using DDT were attempted since the work was done prior to its development. Applications of dusts will not impair the quality of the material produced.

Snout beetles appeared in early June and seemingly caused little injury at the time. Later, the larvae from the beetles caused considerable damage by boring into the stems. This stalk borer can be controlled only by killing the adults. The sulfur-arsenate dust was as satisfactory as any remedy applied.

Cost of Production

No accurate data are available as to the expense entailed in growing *A. belladonna*. It is estimated that it costs between $175 and $250 to produce an acre of *A. belladonna*. This cost will vary with methods of culture, pest control measures, and season.

Summary

Germination.—To secure high germination, immerse seeds for 60 to 100 seconds in commercial sulfuric acid, soak in water for 24 hours, and sow in sandy medium. Maintain a temperature of 90° F. for one week, then reduce to 60° F.

Pricking off.—No difference in yield was obtained from plants planted out of pots, bands, or flats.

Spacing.—Plants spaced 2 by 2 feet in the field yielded practically the same amount of material per plant as those spaced 12 by 12 inches.

Light.—Reduction of light intensity was detrimental to the total dry weight of material produced and to the synthesis of alkaloids within the plant.

Nutrition.—High nitrogen levels increase production. Low levels of potassium and phosphorus are satisfactory. A pH of 5.5 to 6.5 is most satisfactory.

Time of Fertilizer Application.—To secure higher assays, nitrates should be applied in the vegetative stage.

Greenhouse Production.—Production from *A. belladonna* grown in the greenhouse was not as high as from that grown outdoors. Greenhouse production is definitely not profitable.

Colchicine.—Treatments proved ineffective.

Hardening.—Treatment prior to planting is conducive to quicker establishment in the field and higher yields.

Harvesting.—Stems could be cut to within 6-8 inches of the soil level without endangering the continued growth of the plant.

Time of Harvest.—The highest assays are secured when harvesting takes place during the flowering period.

Alkaloid Location.—Alkaloids are greater in immature foliage.

Alkaloid Relocation.—When mature plants are cured whole, regardless of upright or inverted position, the quantity of alkaloids in the roots is diminished and the quantity in the foliage is increased. If the roots are removed, the alkaloid ordinarily present in the stems is shifted to the leaves.

Insect Control.—Insects can be controlled by keeping the foliage covered with a stomach poison dust.

Mulching.—In light soils, a heavy mulch may be conducive to overwinter survival. In heavy soils, a medium mulch is more desirable. Winter survival may also be increased by reduction of the soil nitrogen level to 10 to 15 p. p. m. toward the end of the growing season.

DIGITALIS TESTS

Digitalis purpurea, commonly called foxglove, is a biennial pubescent herb which, during the first year, grows in a dense rosette. The second year the plant produces a raceme of purple flowers on a stalk 3 to 4 feet high, which is highly ornamental. This plant is extensively cultivated both as a garden flower and as a drug plant. Having escaped cultivation, it grows wild in New York, Oregon, and Washington.

The dried leaves of this plant comprise the crude drug Digitalis, of primary importance in the field of medicine and recognized by the United States Pharmacopoeia along with six derived products and two more listed in the National Formulary. The medicinally active ingredients obtained from the leaves include "digitoxin" and other cardioactive glycosides. Due to the presence of these substances, the drug is used as a heart stimulant and diuretic.

The studies of *Digitalis purpurea* which were conducted consisted of seed germination, transplanting, light, and spacing tests.

Germination

Table 19 shows the mediums used, the methods of watering, and the percent of germination for *Digitalis purpurea.*

TABLE 19.—*Digitalis purpurea* **germination tests***

Medium	Watering method	Days to germinate	Percent germination
Soil, sand, peat	2 wicks	8	23
	1 wick	8	9
	Overhead	6	40
Soil, sand	2 wicks	8	40
	1 wick	8	15
	Overhead	8	56
Sand, peat	2 wicks	8	46
	1 wick	11	11
	Overhead	6	65
Soil, sand, sphagnum	2 wicks	11	29
	1 wick	11	24
	Overhead	8	25
Peat	2 wicks	8	21
	1 wick	8	22
	Overhead	11	15

*Seeds for these tests were sown March 6 and pricked off April 9, 1942.

The highest percentage germination was obtained using equal parts sand and peat with overhead watering.

Propagation

To determine the most suitable treatment of the plant for field planting and future production, plants were pricked off into flats, 2½-inch pots, and 2-inch wooden plant bands. These plants were then put in the field. Where wooden plant bands were used, they were not removed from the soil ball, when planting out. Table 20 shows the production in dry weight. Plants were spaced 12 inches by 12 inches.

TABLE 20.—Yield of *Digitalis purpurea*, planted May 13

Treatment	Number of harvests	Pounds per acre
From 2-inch wooden bands	4	6,893
From 2½-inch pots	4	5,096
From flats	4	5,817

The high yield from those planted with bands is a result of more rapid establishment in the field, made possible by eliminating a check in growth at time of transplanting.

Light

Similar plots of digitalis were planted in a lath house, cloth house, and in the open to determine the effect of light in the production of plant material. The results are shown in table 21.

TABLE 21.—Production of *Digitalis purpurea* under varying light conditions (planted May 13)

Treatment	Number of harvests	Pounds per acre
Lath house, 3,500 light candles	3	3,100
Cloth house, 4,000 light candles	6	5,520
Outside, 6,000 light candles	4	6,893

It is quite evident that a reduction in light intensity reduces the yield. This was shown in work with *A. belladonna* as well.

Spacing

In 1943, plots were planted with varied spacing of the plants. The results are shown in table 22.

TABLE 22.—Production of *Digitalis purpurea* in spacing tests

Spacing	Plants per acre	Grams per plant	Pounds per acre (dry weight)
12 inches × 12 inches	43,560	16.75	1,608
18 inches × 18 inches	19,360	26.51	1,133
24 inches × 24 inches	10,890	14.10	259

As would be expected, the largest number of plants per acre yielded the highest amount of material. The 18- by 18-inch spacing produced the most material per plant, however, and depending on cost of seed or started plants could yield as much return per acre as the 12- by 12-inch spacing because of the fewer plants and the lower planting cost.

Observations and Recommendations

Digitalis purpurea is relatively easily grown. There is no doubt that better germination could be obtained through more detailed study and testing, as was done with *A. belladonna.*

Observation of numerous plots grown show that a well-drained soil is essential.

Frequent harvests, collecting individual leaves when they obtain maximum size, did not prove economical. Cutting the whole plant 4 to 5 inches above the soil and harvesting less frequently proved more satisfactory.

The plant material dried in 2 to 4 weeks when spread out on cloth trays in a dry, well-ventilated building. An artificial dryer is recommended when available.

Summary

1. Sixty percent germination of *D. purpurea* seeds can be expected if properly sown.

2. Planting in the field with bands intact proved more satisfactory than planting from pots or flats.

3. Reduction in light intensity decreases the dry weight yield.

4. The most practical spacing of plants is 18 inches by 18 inches.

CULTURE OF MISCELLANEOUS DRUG PLANTS

Though the majority of the research was centered on *A. Belladonna* and *D. Purpurea* plants, a number of other medicinal plants were grown. These genera included only those plants which are suitable for Ohio.

Althea

Althea Officinalis (Malvaceae)

The root, deprived of its bark and cured by drying, constitutes the official United States Pharmacopoeia crude drug, althea, commonly known as marshmallow root. One preparation made from it is listed in the National Formulary. The plant is native to Europe, but has become naturalized in the United States.

Althea should grow well in almost any loose soil of moderate fertility, but it tends to winterkill where freezing goes to considerable depth. Plants may be propagated from seeds or from division of the old roots made in early spring. Seeds should be sown in open, shallow drills at least 3 feet apart, and 16 inches apart in the rows. Seed germination averaging 40 percent occurs in about 8 days in a medium of soil and sand watered overhead.

The roots are collected in the fall of the second year of growth, washed, peeled, cut into small cubes, and dried. Yields of 800 to 1,000 pounds of dry root per acre have been reported. The leaves, also frequently used, may be collected and dried at the same time as the roots. The dried root contains up to 35 percent by weight of a mucous-like substance, while the leaves contain smaller amounts. The main use of the crude drug is in the preparation of soothing applications for the mucous membranes.

Observation plots in Ohio attained a height of over 4 feet and were well adapted to a sandy loam soil with fair drainage. The plant should do well in any section of Ohio.

Angelica

Archangelica Officinalis (Umbelliferae)

The fruits, rhizomes, and roots of angelica are used for their content of a volatile oil which is used medicinally as a carminative and as a perfume and flavor in bitters, cakes, candies, and certain liquors. The plant is indigenous to northern Europe and Siberia, and has been cultivated to slight extent in North America.

Angelica is readily propagated from division of old roots and may be set out in the fall or spring. The plant may also be propagated by seeding into flats and transplanting into the field later, or it may be sown directly into deep, fairly rich loam soil in rows which are later thinned. This requires about 8 to 11 pounds of seeds per acre. Optimum spacing is at intervals of 18 inches in rows 3 feet apart. Seeds germinate poorly if over a year old. They are frequently sown into well-watered, well-drained, deeply-plowed beds immediately upon ripening.

The practice of cutting off flowering tops to force root growth has been reported.

The crop yield is 900 to 1,300 pounds of the usable material per acre. The fruit is collected in the green, tender stage just prior to ripening and is dried in the shade. In the fall of the second year, the rhizomes and roots are dug up, cleaned, cut into slices or strips, and carefully dried.

The plants under observation grew to approximately 14 inches in height, bearing an abundance of fruit. According to literature reviewed, the lake regions of Ohio could best afford the proper conditions for production of this drug.

Anise

Pimpinella anisum (Umbelliferae)

Aniseed, or anise seed as it is popularly called, is the dried ripe fruit of this plant and is officially recognized in the National Formulary. Volatile oil of anise and two other derived preparations are official in the United States Pharmacopoeia. The plant is indigenous to Egypt and to several of the Mediterranean islands. The ancients valued this plant highly for its flavor and medicinal values.

Seeds are sown directly in the field and subsequently thinned in the rows, or are sown in flats in the greenhouse. The young plants should be hardened in cold frames before setting out in the field in the latter part of May. Basic cultivation requirements are a light, well-drained, fertile, sandy loam. Anise has a growing period of from 130 to 140 days and should therefore be sown early in March in Ohio. Germination in soil and sand medium will occur in 10 to 12 days with seeds less than 2 years old. The young plants are set in the field spaced 12 by 12 inches. Harvesting of the fruits begins when the stem of the plant begins to turn yellow and the fruits in the middle of the umbel take on a greenish-gray hue. The whole plant may be cut down, dried, and then thrashed to obtain the dried, ripe fruit. The volatile oil is obtained by subjecting

the fruiting tops of the plant to steam distillation without drying. Yield of the fruit is from 400 to 600 pounds per acre. Medicinally, the oil is used as a carminative and a flavor for other preparations.

Experimental plots of anise, despite their susceptibility to constant insect attack, attained growths of 24 to 36 inches in height. The best production could probably be obtained from plantings in the valleys of the southern part of Ohio, protected from early and late frosts.

Capsicum

Capsicum frutescens (Solanaceae)

Commonly known as the cayenne pepper, red pepper, African chillies, or tabasco pepper of commerce, capsicum is officially defined in the National Formulary as the dried ripe fruit of the plant. Capsicum is a small spreading shrub, indigenous to tropical Africa, India, America, and Japan.

Seeds of this plant germinate about 60 percent in 11 days when planted in a medium of peat to which water is applied overhead. The young plants, pricked off, are held in the greenhouse or cold frame until approximately the middle of May, and then are set out in rows 3 feet apart with 10 to 12 inches between each plant. The fruit is harvested when ripe and carefully dried. In the ripe stage, the fruits are a bright red and the calyx adheres. The calyx is removed. Care must be taken in handling the dried peppers to keep fragments of the broken specimens away from the eyes, nose, and mouth.

The highly irritant constituent of the fruits is a principle known as *capsaicin*. Due to its presence, preparations of this drug are used as counter-irritants, stomachics, and condiments.

In Ohio, capsicum grows up to 25 inches high under practically any condition where adequate plant nutrients are available. Observation plants were highly productive of bright red fruit rendering the deep green plants richly ornamental.

Caraway

Carum carvi (Umbelliferae)

Official in the United States Pharmacopoeia, caraway is defined as the dried ripe fruit of this plant and is commonly called for by the name caraway seed. The plant is a biennial herb which has been naturalized

in the United States and Canada. It grows wild in Asia and Europe, and is cultivated in Germany, Morocco, Spain, Norway, Russia, England, and to some extent in northern United States.

Good seed will germinate approximately 84 percent in 7 to 10 days in a medium of sand and peat, with a constant water supply from below provided by two wicks per flat. Seeding is done in March, and after the young plants have been pricked off they should be held inside until danger of frost is past. When frost has left the soil, caraway may also be drilled in the field in rows 16 inches apart, using 6 to 8 pounds of seeds per acre. Caraway will grow in a wide range of soil conditions but probably does best on an upland fertile clay, frequently cultivated. It will withstand a rather severe climate. Yields of 800 to 1,200 pounds of the fruit per acre may be expected under favorable conditions. Caraway should be collected just prior to complete ripening of the fruits, dried in the shade, and then thrashed, screened, and packaged. The principle constituent, oil of caraway, official in the National Formulary, is obtained by steam distillation of the fruits and tops of the plant without drying.

In medicine, the oil of caraway is used as a stomachic and carminative. It is also employed in the production of pastry, cheese, salads, sauces, soups, candy, perfumes, soaps, and liquors. Besides the essential oil, there is a fixed oil existing in the fruits in the amount of about 15 percent by weight, termed "butter fat." Consequently, the "marc" left after distillation of the volatile oil is a valuable feed for livestock.

Ohio-grown plants fruit heavily and are adapted to conditions throughout the state, though perhaps more favorable to the hilly areas in the southern part of the state.

Chenopodium

Chenopodium ambrosioides, var. *anthelminticum (Chonopodiaceae)*

The popular name of the plant is American wormseed and the drug obtained from it consists of the dried fruits. Chenopodium is native to the West Indies, and Central and South America. It is an annual or perennial weed growing in waste localities in the United States, where it has become naturalized.

The seed germinates at about 80 percent within 7 to 9 days in a medium of soil and sand watered overhead. Young plants are pricked off and held in the greenhouse or cold frame until time to set them in the field as determined by weather conditions. Seeds have been successfully

sown directly in the field in early spring. Seeds are drilled in the field about 1 inch apart in rows 3 inches wide. If the crop is grown for the seed, harvesting should be carried out just before the tops take on a brown color. The plants are cut, allowed to dry thoroughly, and then thrashed or stripped. The seed should be screened before sacking for market.

The active constituent is a volatile oil yielding *ascaridole,* the anthelmintic principle, and is obtained by steam distillation of the fresh whole plant just prior to ripening of the fruits. This volatile oil is officially recognized by the United States Pharmacopoeia. The fruits and oil are used in preparations for preventing and treating infestations of round and hook worms in man and animal.

Ohio-grown plants attain heights of about 36 inches, producing fairly heavy yields of fruits. The plants are probably best suited to western Ohio's level plains with hot sun and well-drained soils.

Coriander

Coriandrum sativum (Umbelliferae)

Coriander, official in the National Formulary, is the dried ripe fruit of this plant and is synonymously known as coriander seed. The plant is an annual, indigenous to the Mediterranean or Caucasian region. It has been naturalized in the United States and is cultivated in Africa and India. In approximately 11 days, the seed germinates on an average of 91 percent in a medium consisting of soil, sand, and sphagnum, to which water is applied from overhead. In the field, seeds are sown in April at the rate of 10 pounds per acre in drills 1 foot apart. The propagation, culture, and harvesting of coriander is essentially the same as that for caraway, except that coriander is harvested every year whereas caraway produces one crop every 2 years. Coriander is easily cultivated, growing in almost any soil except ground with poor drainage, and will mature in a 90-day season. The crop yield is from 750 to 2,200 pounds of the dried fruit per acre. This wide variation is due to some fruit not filling out at maturity. The fruit is collected as it begins to ripen. Experiments show that the material in the early green stage yields an average of 0.49 percent of volatile oil; in the intermediate green-purple stage it yields only about 0.40 percent; and the fruits in the late brown stage of ripening yield only 0.30 percent of volatile oil. The fruits are dried either in shade or in sunlight. If the volatile oil of coriander is desired, the fresh fruits and tops of the plant are subjected to steam distillation.

Oil of coriander is offiicially recognized in the United States Pharmacopoeia. It is used as a carminative and to decrease the griping effect of some of the strong cathartics. It is also utilized in the condiment, baking, and conserving industries, as well as in flavoring liquors.

Coriander grown in Ohio attains a height of 20 to 28 inches and produces abundant fruit, the average yield of which is over 1,500 pounds per acre. The plant is suitable for production throughout the state of Ohio.

Fennel

Foeniculum vulgare (Umbelliferae)

From cultivated varieties of this plant is obtained the crude drug commonly known as fennel fruit or fennel seed. The volatile oil of fennel and one other preparation utilizing the fruit of fennel are officially recognized by the United States Pharmacopoeia.

The plant is a biennial or perennial which grows almost anywhere, particularly in Spain, southern France, Macedonia, and southern Russia. It can be cultivated in a fairly mild climate and on nearly any soil, but thrives on non-acid, well-drained loams. It is readily grown from seed, but also can be propagated by root and crown division. In the field, seeds are sown thickly in drills 3 feet apart at the rate of 4 to 6 pounds of seeds per acre and should be provided with a light cover. Later the plants may be thinned to stand 15 inches apart in the row.

The crop yield is from 800 pounds in the first year up to 1,400 pounds per acre in the years immediately following. The fruit is collected just as it begins to ripen and turn color. The volatile oil, obtained by steam distillation, is used as a carminative and a flavoring agent for bitter tasting medicinals. The dried ripe fruit has been used as a galactagogue (milk stimulant) in pharmaceuticals and in the industries for preparation of pastry, candy, canned fruits, cheese, meat preserves, and fruit preserves. After the oil has been distilled from the fruit, the remainder, known as the "marc," may be utilized as cattle and chicken feed.

Ohio-grown plants attained a height of over 4 feet and bore abundant fruits despite continuous insect attacks. It is believed that the plant would produce optimum growth in wind- and frost-protected valleys of southern Ohio.

Hyoscyamus

Hyoscyamus niger (Solanaceae)

Henbane, hog bean, and stinking nightshade are the common names applied to hyoscyamus, defined as the dried leaf, with or without the tops, of this plant. This crude drug and three derived preparations are listed in the United States Pharmacopoeia. One preparation appears in the National Formulary.

Henbane is a biennial or annual native to Europe and Asia. It is found growing wild in lower Canada and north central United States. Major supplies of the herb were obtained from Egypt, Russia, and Hungary before World War II. As early as 1918, it was demonstrated in Michigan and California that the plant could be successfully applied to large scale cultivation in the United States.

The culture of hyoscyamus is comparable to that of belladonna but requires more careful attention. British growers recommend that the soil be thoroughly cultivated and cleaned in autumn and the seeds sown then or early the next spring by drilling in rows 2 feet apart. This requires about a pound of seed per acre. Plants are singled down to 8 inches apart in rows when well established. This procedure is reported to yield two crops of leaves the first year and usually three the second year, after which the remains of the plants are plowed under to enrich the soil for some cereal crop in the following season's rotation. Due to variability in seed germination in the past, open field sowing has not been recommended in this country. Recent germination averages of 84 percent within 10 days have been obtained in peat, watered from below with one wick per flat.

Seedlings are successfully transferred to 3-inch wooden plant bands within 4 weeks, and as soon as the weather permits they are transplanted in the field in a moist condition, freed from bands. Care must be taken to prevent injury to roots at this time or the transplant may be unsuccessful. Spacing is usually 12 to 15 inches in rows about 2 feet apart.

Dusting the plants the first year with insecticides is essential to prevent various beetles from laying eggs in or on the plants. If larvae are allowed to develop early in the second year, they frequently destroy the pith of the stems and may even be found mining the larger roots. A high mortality rate results if this development occurs since no treatment is available for the destruction of the larvae inside the plant stems.

Hyoscyamus is usually harvested when in full bloom if it is the biennial, flowering variety. A crop may be harvested each year from the annual plant, amounting to as much as 2,800 pounds per acre. The biennal produces a good crop only every second year.

The active principles of hyoscyamus are the alkaloids *hyoscyamine* and *scopolamine* which render the crude drug preparations useful in checking vesical spasms in urinary incontinence, in decreasing the griping action of purgatives, as a sedative to the central nervous system in delirium tremens and tetanus, and as mydriatics and cycloplegics in ophthalmology.

Like belladonna, hyoscyamus is adaptable to varied conditions of growth and with suitable care should produce abundantly in almost any section of Ohio.

Lavender

Lavandula officinalis and *L. vera (Labiatae)*

The crude drug lavender flowers, as it is known to the laiety, is obtained from this plant which was first introduced to this country from the Mediterranean region. Lavender bushes are small perennials with woody, sinuous stems, straight leaves, and small bluish flowers. The plant may be grown from seeds in flats and later transferred, but it is usually propagated by cuttings or small branches with a root or heel pulled off the larger plants. These may be set in the field at 18-inch intervals in rows 2 feet apart. Planting may be done in October or early spring. The plants are maintained for about 5 years before replacing them with fresh stock. Flowering is prevented the first year by cutting of the tops. Lavender thrives best in light sandy loam and rather dry soils. Plantings should be in well-drained and sunny locations. Deep, thorough cultivation is essential.

The flowering tops of the plant are collected, carefully dried in the shade, and then the flowers are removed by stripping. The volatile oil of lavender, recognized officially by the United States Pharmocopoeia, is obtained by steam distillation of the freshly-cut flowering tops. The yield of this oil per acre of plants is from 12 to 20 pounds. Two other preparations utilizing a product of lavender are official in the United States Pharmacopoeia. The more important uses of the volatile oil are as a carminative and a perfume in pharmaceuticals and cosmetics.

Growth characteristics indicate that Ohio plants will produce more abundantly when grown in light sandy loam in the southern and western parts of the state.

Pyrethrum

Chrysanthemum cinerariaefolium (Compositae)

The crude drug obtained from this source is commonly known as insect flowers and consists of the dried flower heads collected when the flowers have just begun to expand. The plant is indigenous to southern and central Europe.

Experimentation with seeds of the plant has demonstrated germination up to 47 percent in approximately 11 days when planted in a medium of sand and peat watered from overhead. Sowing may be done in late summer or early spring, plants being set in the field in April or May with spacing of about 21 inches in rows 2 feet apart. The plants grow well in soil with good drainage and no shade, thriving on the midwestern plains and in sections of California. Addition of lime to the soil at the rate of 4 tons per acre is advised by the British. Usually one season is required for the plants to become established, after which yields of 400 to 500 pounds per acre may be expected. The flower heads are picked mechanically or by hand, and are dried in sunlight or artificial heat below 160° F.

The purpose of production of the drug is as a source for the pyrethrins, insecticidal principles, used in parasiticide lotions and in the control of insects.

Plants grown in Ohio in sandy loam attained heights of about 30 to 36 inches, bearing up to 14 flower heads per plant. The various publications on drug plant culture and the plant characteristics suggest that the plants could be grown best in central, western, and southern Ohio.

Ricinus

Ricinus communis (Euphorbiaceae)

Ricinus, the dried ripened seed of this plant, is not official itself, but produces the fixed vegetable oil known as castor oil which is listed in the United States Pharmacopoeia along with one other derived preparation. Ricinus is commonly known as castor bean. Its original habitat is India, although at present it is widely naturalized throughout the world.

Any soil suitable for production of good crops of corn will usually be found suitable for ricinus also. Enrichment of the soil during the growth of the crop may increase the size of the plant and decrease the seed production and early maturity. Early maturation of seed is essential in evading frost in northern areas. As early in the spring as weather

permits, seeds are sown in well-cultivated soil, 2 or 3 seeds to a hill in rows about 4 feet apart. The hills are usually spaced 3 feet in the row and are provided with a shallow cover of 1 or 2 inches of soil. About a bushel of well-filled seeds will be sufficient to plant 5 acres. When the plants are well established, they are thinned to 1 per hill.

When ripe, the fruits, which are borne in spikes, are collected and dried. The seeds may drop from the dried pods or may have to be collected by crushing the pods and separating by sifting and fanning. Reported yields range from 8 to 25 bushels per acre.

Suitable to widely varied soils and climatic conditions, ricinus grows 6 to 40 feet tall, depending upon the variety and environmental conditions. In the tropics it is perennial, but it is killed by frost. The seed is about the size of a bean, often enclosed in a spiny covering. They vary greatly in size and markings, and contain 65 to 80 percent of kernel which has 35 to 55 percent of the fixed oil. The seeds contain an extremely poisonous substance, *ricin,* which renders the press cake unsuitable for stock feed, making it undesirable to crush the seeds with the same equipment used for edible oils. The press cake is successfully used as a fertilizer. When the seeds are collected and dried, the oil is obtained by the cold press method.

The plant itself is widely grown as an ornamental, but is chiefly produced for its bland oil. This oil has become increasingly important due to the fact that a special process renders it "quick drying" and therefore valuable in the paint and varnish industry. It is also used in the manufacture of inks, flypaper, electric insulating compositions, toilet creams, hair dressings, and soaps. When combined with ethyl cellulose, it produces a rubber-like material which can be used as a rubber substitute in many cases. It is also employed in the lubrication of delicate machinery and was of great importance in war work. Medicinally, it is purgative and lubricant acting in the intestines to alleviate constipation.

The castor bean plant, grown throughout Ohio for ornamental purposes, could well be placed under extensive cultivation in any section.

Sage

Salvia officinalis (Dabiatae)

This plant is frequently called garden sage. The National Formulary recognizes it as the official source of the crude drug, sage, consisting of the dried leaves of the plant. It is a perennial, low shrub indigenous to the Mediterranean regions and cultivated in various parts of the

United States and Europe for the production of the volatile oil which is steam distilled from the leaves and tops of the fresh plant, and for the dried leaves which are ground and widely used as a condiment. Experiments have shown that the seeds germinate 76 percent in a medium of equal parts of sand, soil, and peat with moisture applied from overhead. Time required for germination is approximately 11 days. Sage is easily cultivated and is generally propagated by seeds. The first year's crop is small, but there is an increase from the second through the fifth year. Any well-drained, fertile soil is suitable but best results have been reported when using a rich clay soil. A yield of 1,500 to 2,000 pounds or more of dried leaves and tops may be expected per acre. Seeds are sown in March, pricked off and planted out after the danger of frost is past. Spacing in the field is 12 inches by 24 inches. Seeds may be sown directly in the field in any well-drained fertile soil in rows 2 feet apart and the plants thinned to 12 inches in the row when well established. Further propagation is carried on from cuttings as the plants frequently do not set seed. A single harvest should be made the first year, after which 2 or 3 may be made in a season. The leaves are dried in the shade, or if the volatile oil is desired the fresh material is steam distilled. Medicinally, the oil is used as a carminative.

Plants grown throughout Ohio have been reported to produce a luxurious, dense growth.

Stramonium

Datura stramonium and *Datura tatula (Solanaceae)*

The United States Pharmocopoeia defines stramonium as the dried leaves and flowering tops of the plant which is commonly known as jimson weed and thornapple. Three derived preparations are official in the United States Pharmacopoeia and two in the National Formulary. Originally from Europe, the plants have become naturalized in fields and wastelands of North America.

Germination of 96 percent occurs in 8 days in a medium of soil, sand, and peat. The plants may be propagated from seeds sown in flats and later transplanted with very little loss. Sowing seeds directly into the field may also be carried on successfully.

In the latter method, early spring drillings, in rows 3 feet apart, should be lightly covered. When plants are about 3 inches high, they are thinned to 15 inches in the row. Cultivation to remove the weeds and application of dust insecticides to young plants lead to increased

yields, reported as high as 4,000 pounds dry weight per acre. The leaves are collected while the plants are in full flower. They may be picked individually in several crops or the entire plant cut at one harvest and cured by hanging up to dry. In order to reduce the time required for normal shade drying, artificial heat below 115° F. may be applied with good circulation.

Adaptability to wide variations of environmental conditions is shown in the fact that the plant grows as a weed in soils from Canada to Texas and from California to Georgia.

The active constituents are the alkaloids of stramonium which include hyoscyamine and atropine. Preparations of the crude drug are used to relax bronchial muscles in asthma, in *paralysis agitans,* and are used to check excessive secretions.

Throughout the state of Ohio, stramonium thrives with little attention, growing as high as 5 feet and producing leaves 9 inches broad.

Thyme

Thymus vulgaris (Labiatae)

Thyme, garden thyme, or common thyme is recognized by the National Formulary as the official source of the crude drug consisting of the dried leaves and flowering tops. Two preparations using this material are also listed in the National Formulary. The plant is a shrub-like perennial of the mint family, native to southwestern Europe. It is a common garden plant which lives for many years under proper cultivation. Propagation methods utilize seeds or cuttings set in sand under glass. Seeds sown directly into the field are planted as soon as the soil is frost-free. Drills 3 feet apart may be thinned to a spacing of 2 to 3 feet in rows as soon as the plants become established. Thyme grows well in fertile sandy loam soil which is cultivated free of weeds throughout the growing season. The annual yields increase for several years. The production from experimental plantings have indicated many variations, but it appears that under good conditions, 1,000 to 2,000 pounds of dried leaves and flowering tops may be expected per acre. Major successful plantings have been undertaken in the northern section of the Middle West and in some localities on the West Coast.

Plantings should be renewed every third year. The crude drug is obtained by cutting off the tender stems and flowering tops when in full bloom and carefully drying in the shade on trays with fine mesh wire or

muslin bottoms. In production of the volatile oil of thyme, the entire plant in full bloom is subjected to steam distillation without drying. The medicinally active ingredient of the plant is the volatile oil yielding *thymol,* an antiseptic phenol.

The leaves of thyme are used in condiments and teas, while the oil is used as a carminative and antiseptic.

Plants grown under observation in Ohio required 2 years to produce the dense growth characteristic of most mint beds. Thyme should be suitable for cultivation throughout Ohio in fertilized fields.

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