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CULTIVATION OF EPHEDRA SINICA IN SOUTH DAKOTA.*,[1]

BY B. V. CHRISTENSEN[2] AND L. D. HINER.[3]

PART I.

The remarkable advance that ephedrine and its related products has made in the field of therapeutics gives to it a distinct importance that relatively few medicinals have enjoyed. Scarcely known in this country some ten years ago when the U. S. P. X and N. F. V became the official standards, ephedrine products are now so extensively used that it was deemed advisable to admit the alkaloid and two of its salts to the U. S. P. XI, and several preparations of them to the N. F. VI. This final assurance of their therapeutic value makes it imperative that Pharmacy and Medicine be assured of a continuous supply of this drug. The prevailing uncertainties which frequently interfere with supplies of imported drugs have already affected our supplies of ephedra and the distinct benefits to be derived from having a domestic source of supply is being recognized. Experimental cultivation of both indigenous and imported species is being encouraged (1).

Doctor Youngken suggested in one of his recent articles that the present Sino-Japanese trouble would very likely affect our supplies of ephedra. Some effects have already been noticed and these have served as added incentives to continue investigation of ephedra cultivation. Although a few plants have been grown here mainly for specimen purposes, reliable and adequate information is meager. It is believed that this is the original attempt to place Ephedra sinica definitely under cultivation in order to determine its possibilities as a commercial drug crop (2).

A fairly complete account of the introduction of Ephedra sinica into South Dakota was contained in a preliminary report made in 1936 (3). The numerous inquiries which have been received for additional information on this experimental work suggested that a more detailed and complete account of the findings up to date, 1938, might be of interest and value.

I. PROPAGATION METHODS.

Seeds were collected during the years of 1933–1937 inclusive and tests made on the first four lots to determine their percentage of germination.

Seed testing was done in the greenhouse where the seeds were sown in shallow flats filled with rich black loam. The seeds were sown in ten evenly spaced rows, with ten seeds per row and covered to a depth of about one-half inch, by sifting on a mixture of equal parts of sand and soil. The seeds were then wetted down and the flats covered with a glass to hasten germination. Tests were carried out on seeds collected the previous growing season.

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[1] Abstract of a thesis presented to the Graduate Council, University of Florida, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

[2] Director, School of Pharmacy, University of Florida.

[3] Professor of Pharmacognosy and Pharmacology, South Dakota State College.

TABLE I.

Collection Date.	Date Planted.	No. of Seeds.	Germinated.	Per Cent.
1933	1934	300	272	90.60
1934	1935	300	239	79.66
1935	1936	300	226	75.30
1936	1937	200	156	78.00
Total Average Germination, 1933–1936				80.64

It may be concluded from this data that Ephedra sinica when grown in South Dakota, produces viable seeds from which it can be successfully propagated. (See Fig. 1.)

These tests, however, having been made under glass, gave no indication of how the seeds would react if sown directly in outdoor plots. Hence, trial plantings were made outside to determine if the seeds would germinate and mature enough in a single season to enable the small seedlings to avoid winter killing. It was desirable also to know how early or late the seeds could be sown with safety. From trial plantings made from 1934 to 1937 the following observations were made:

TABLE II.

Dates Planted.	Germinated.	Estimated Per Cent.	Seedling Report the Next Spring.
3/28/1934	Apr. to June	80	Broadcast plot. Discarded
5/6/1935	5/20/1935	80	Wintered in excellent condition
5/19/1936	6/1/1936	Fair	Wintered in excellent condition
4/19/1937	5/6/1937	90	Wintered in excellent condition

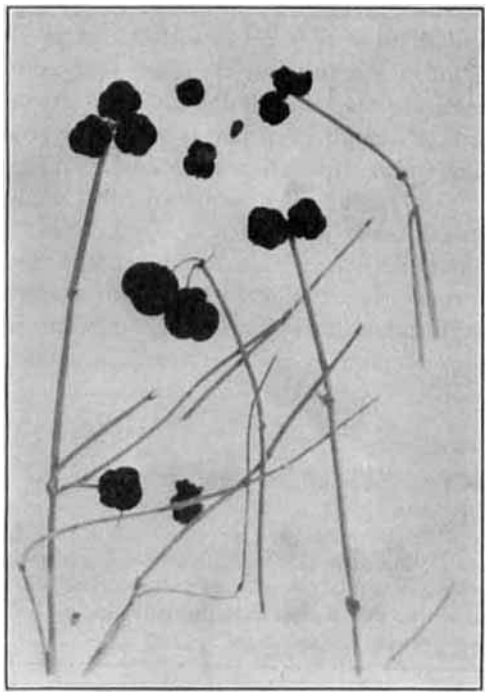

Fig. 1.—*South Dakota Ephedra Sinica.* Fruits of Ephedra sinica, 1/2 natural size. Each berry-like fruit holds two seeds, one of which is shown in the picture.

Ephedra sinica seed, therefore, may be sown outside in the spring, just as soon as the beds can be prepared for sowing. Seeds sown between the dates of March 28th and May 19th. germinated well and even the latter date allowed time for the young plants to develop so that they were able to winter in the field.

Various methods of seed planting were also tried in the outdoor plots in an attempt to find how they should be sown. In 1934 broadcast seeding was tried in hopes that the plants might more quickly produce a covering which would prevent wind erosion. The seeds were sown by hand and disked in with a small hand disk. Seed germination in this plot was scattered due, no doubt, to the various depths to which they had been covered by the disk. For this reason it was extremely difficult to keep the beds clean without damaging the ephedra for many of the smaller plants were pulled up along with the weeds. Although germination was finally estimated at about eight per cent, the method was discontinued after the initial trial.

Garden planters and drills were tested out in 1935 but the results were far from satisfactory. The uneven spacing of the plants in the rows made it difficult to tend the small plants.

The seeds sown in rows according to the following directions gave the best results: (1) Prepare the bed early by spading it up and carefully raking it over and then allow the loose soil to settle before planting. (2) Make the rows by creasing the top soil with the sharp edge of a board to a depth of one-half to three-quarters of an inch. (3) Plant the seeds in these rows one to two inches apart, and cover them with a mixture of equal parts of sand and soil. Press down firmly. (4) Keep the beds well watered until the seeds have germinated. The rows should be at least thirty inches apart so as to prevent packing of the soil around the small plants during cultivation.

Seeds planted according to these specifications gave an improved germination count over the other methods tried. The above spacing of the seedlings also allowed freedom of cultivation and gave the small plants plenty of room for development until such time as they were ready for transplanting to the field at the end of their second or third growing season.

The very excellent results obtained from seeds sown directly into the garden plots made planting under glass unnecessary except for seed testing, where actual germination was recorded and no attempt was made to save the plants for the field. "Damping off" proved a serious menace to the early starting of plants in the greenhouse. Even in sterilized soils it was difficult to control, and very soon discouraged anything but field planting in the outdoor plots. Considering the extreme adversity of the seasons the plants started from seeds have come through, it is reasonable to conclude that ephedra can be successfully propagated from seeds sown directly in outdoor beds

PROPAGATION FROM ROOT STOCK.

The first attempts to subdivide the older plants and so increase their number were unsuccessful for the numerous stems all seemed to join the one main root system. It was noticed though that as the plants matured they sent out lateral rhizomes which approached the surface of the ground and then developed stems only at their tip ends while still attached to the old plants. By working around the older plants with a long sharp spade, the rhizomes could be cut and stimulated to increase their own root system. By cutting these new shoots and then allowing them to remain undisturbed until the next spring, they could be transplanted with scarcely the loss of a single plant. This proved to be a convenient and rapid means of increasing the number of plants.

Again in the spring of 1937 after the plants had matured a little more, another attempt was made to subdivide the larger clumps of ephedra. Apparently the more favorable growing conditions had stimulated them to a vigorous production of new rhizomes which had clustered in close to the old plant as they matured. These were all massed together in a tangle of roots which necessitated cutting before they could be separated into the individual plants suitable for transplanting. Best results were obtained by dividing these older plants in the spring before active growth had started, although ephedra transplanted very well at any time during the summer. A transplant record was kept in order to have a check on the relative number of plants lost during propagation procedures. The results are shown in Table III.

TABLE III.

Year.	No. Transplanted.	Plants Lost.	Per Cent Mortality.
1934	73 from rhizomes	2	2.7 negligible
1935	120 from rhizomes	2	1.6 negligible
1936	24 seedlings	0	0 negligible
1937	450 from rhizomes	50	11.1 moderate

Ephedra transplants very well, especially when care is taken to use plenty of water around the plants when they are reset.

During the process of propagation, note was made of the spacing of the plants so as to determine the area which should be allowed for each plant when they were placed permanently. Spaced as they were in 1935, an acre would accommodate about 8,904 plants. However, by the end of the 1936 growing season, the plants were very obviously crowding each other in these plots as evidenced by the more vigorous development of their neighbors which were spaced farther apart. Leaving ample room for cultivation along the edges of the field, it is estimated that an acre should take about 6,500 plants. This would allow ample room for the plants to stool out and the rhizomes would soon fill in the intervening spaces to form a sod.

SUMMARY AND CONCLUSIONS.

A study was made to determine the quality of Ephedra sinica seeds produced in South Dakota and to investigate the possibilities of propagating the species from both seeds and root stock. An attempt was also made to root stem cuttings of ephedra. From the information collected the following conclusions are possible:

1. Ephedra sinica produces viable seeds of good quality when grown in South Dakota.
2. Propagation from seeds is best handled by sowing the seeds in rows, directly in the outdoor plots.
3. Ephedra sinica can be propagated from its root stock.
4. Stem cuttings did not root.
5. It is estimated that an acre should accommodate about 6,500 plants.

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(1) Youngken, H. W., *Am. J. Pharm. Ed.*, 2, 241 (1938).
(2) Youngken, H. W., *Herbarist*, No. 3, 12 (1937).
(3) Christensen, B. V., and Hiner, L. D., JOUR. A. PH. A., 25, 969 (1936).

II. CULTURAL INVESTIGATION.

Coincident with the experimental work on propagation methods for ephedra, observations were likewise being made on the problems pertaining to cultivation of the plants in the field. The mere fact that a species can be propagated in a locality is no assurance of its suitability for commercial cultivation. Such factors as climatic adaptation, soil types, topography, may entirely eliminate such possibility. This investigation was carried out to determine if any of these factors might limit the production of ephedra in South Dakota.

Naturally, the first point of interest in the introduction of a foreign species is whether or not it is climatically adapted to its new environment. Because of the extremely variable winters in South Dakota it was predicted that some of the plants would surely be killed. This would of course necessitate replanting each spring to fill in for missing plants. It would be desirable to determine about what per cent this would be in order to have sufficient plants coming on for replacements. The possibility of using mulches to reduce winter killing was also considered.

The winter of 1933–1934, according to the garden records, was dry and open with very little snow during the cold months. South Dakota suffered its worst "black blizzards" of eroding top soil the next spring for there was no moisture to prevent the soil from blowing. In spite of these adverse weather conditions the number of plants lost by winter killing was negligible.

The 1934–1935 winter months were average with enough snowfall to mulch the plants well, and a moderate amount of cold weather. No plants were lost as shown by a check of the beds in the spring of 1935. During this winter uncut plants were left in the field on the supposition that the stems might be perennial like the roots, and that allowing them to mature might increase their seed production and alkaloid content. Enough were left uncut so some could be matured into their fourth and fifth growing seasons should it be desirable.

The winter of 1935–1936 and the growing season of the latter year gave the ephedra plants a real opportunity to prove themselves. Several weeks of 30° to 40° below zero weather during January and February established it as the coldest South Dakota winter in fifty years. During this weather the plants remained upright, blackened in color considerably, but when the final spring check was made only one plant was missing.

The growing season which followed was one to tax the endurance of even the most deeply rooted and hardy perennials. July and August were marked by unusually hot and dry winds blowing in from the parched Southern states which literally seared most of the green vegetation. Grasshoppers were abundant too and this combination left the state rather barren in several spots. In spite of this, the ephedras recovered from the cold winter, increased seed and stem pro-

duction and, unmolested by the grasshoppers, they took advantage of the late fall rains which sent them into the winter in excellent condition.

Again in 1936–1937, the winter months were fairly mild, and characterized by an abundance of snowfall. Deep drifts covered the plants all winter and again none were lost. After watching the plants through these several seasons, there remains not the slightest doubt of their ability to withstand the rigors of South Dakota's climate.

The use of mulching was continued from 1934 through the winter of 1937. Results are indicated in Table IV.

TABLE IV.

Winter.	No. Mulched.	Unprotected.	Plants Lost.
1933–1934	25	200	None
1934–1935	24	200	None
1935–1936	24	250	One mulched plant
1936–1937	24	250	None

A variety of material was used in these mulch tests. Straw was raked in close around some so that it did not bend the stems down. Others were completely covered with leaves and straw and some were mulched with cornstalks to support the weight of the straw which was thrown on top. This was done to allow for freedom of circulation about the stems underneath.

It was observed that mulches not only were unnecessary, but were even a disadvantage to the plants. Frost persisted much longer under the mulch when spring opened and during the melting of the snow many stems were bent down and frozen into the ice. Ephedra naturally tends to collect its own mulch of leaves and snow, making artificial mulching quite unnecessary. (See Fig. 2.)

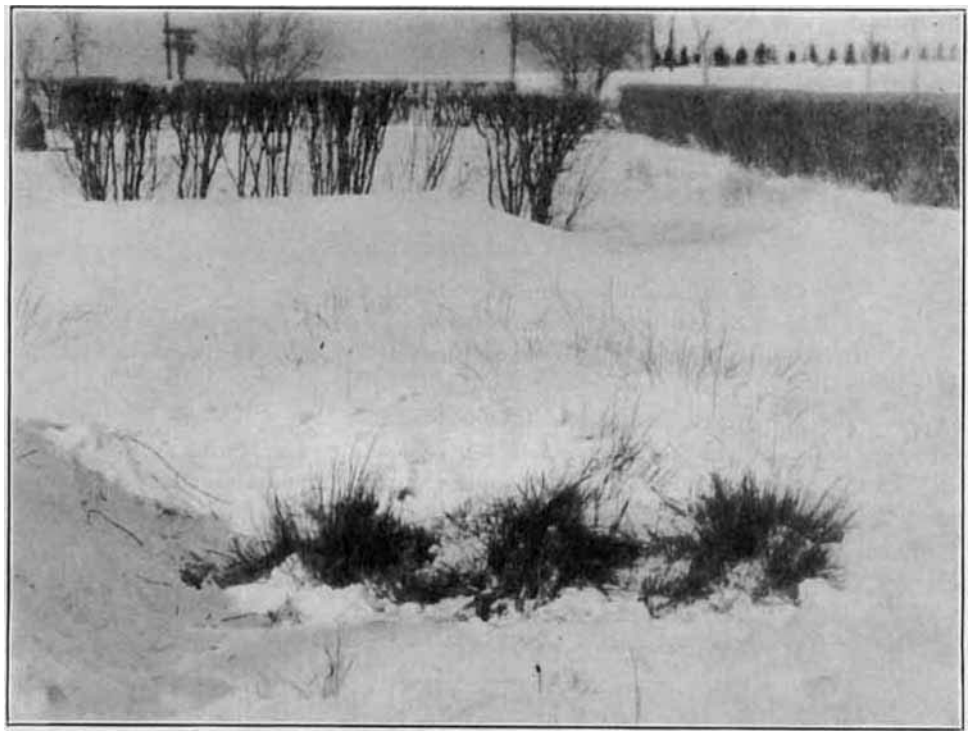

Fig. 2.—*South Dakota Ephedra Sinica*. Ephedra naturally tends to collect its own mulch by its numerous erect stems which catch blowing snow and leaves. The snow was removed from these plants to illustrate the natural position they maintain during the winter. The tops of the other plants in the plot can be seen protruding through the deep mulch of fallen snow.

In order to determine the hardiness of ephedra among the native weeds and grasses, some mature plants were transplanted directly into a plot of quack grass and weeds. They continued to grow and appeared to stand the dry, hot weather better than the weeds and grass. At the end of three years, the ephedra had stooled out and formed a tough sod and was choking out the quack grass. It has also been observed that the ephedra rhizomes are now spreading out through the sod paths which border the plots. Once ephedra becomes established, it is seemingly not hampered in its development by the presence of other vegetation.

The summer of 1935 was very favorable for observing what effect stem rusts, smuts and molds would have on the plants. Unusual rust and smut damage was suffered in that locality where the ephedra plants were located, but they showed no signs of infestation. According to Dr. Stakeman, University of Minnesota Plant Pathologist and authority on rusts and smuts, there are innumerable physiological strains of these plant pathogens, some of which are specific in the host plants which they seek. To be certain the ephedras had not by chance escaped strains to which they might be susceptible, numerous samples were collected from wheat, oats, rye, barley and corn in the agronomy test plots and deliberate attempts were made to inoculate the ephedra stems. None of these inoculations were successful and strongly indicated that ephedra was not susceptible to the rusts and smuts used in the experiment, nor to those which it has thus far contacted as it grows in the field.

No evidences of insect damage to the ephedra plants have been observed. To be certain, however, various insects which are common to this area were confined in cages with grass and ephedra stems. While insects ate freely of grasses under the cage, they died before more than nibbling the ephedra stems. An ephedra plot and one of spearmint were separated by a narrow grass path. During the summer of 1936 the spearmint was completely devoured by the hoppers and crickets while the ephedra remained untouched. The tests and observations indicate that ephedra is not palatable to the common insects which ordinarily are a menace to crops.

Further cultural experimentation indicated that checking the plants in, in evenly spaced rows so that cross cultivation was possible was the most satisfactory method. Single row shovel cultivators were found satisfactory to keep the soil friable until the plants stooled out forming a sod which made further cultivation unnecessary. Considerable hand weeding was required, however, from then until the sod was complete enough to control the weeds. Eventually the plants produced a growth of stems so heavy that further cultivation was unnecessary except for occasional persistent weeds. Cultivation of ephedra appears to be fairly simple and comparable to that of ordinary farm crops.

SUMMARY AND CONCLUSIONS.

1. Ephedra is climatically adapted to South Dakota.
2. Mulching of the plants is unnecessary.
3. Ephedra is essentially a dry land plant and doesn't thrive in low wet surroundings.
4. The plants are disease and insect resistant.
5. Cultivation is best carried out by checking the plants in rows where they can be cultivated until they form a sod, which makes further cultivation unnecessary.

REFERENCES.

(1) Christensen, B. V., and Hiner, L. D., JOUR. A. PH. A., 25, 969 (1936).
(2) Read, B. E., "Flora Sinensis, Ephedra," Series B, Vol. XXIV, 1, 21 (1930).
(3) Rusby, H. H., and Hart, *Druggist Circular*, 1186 (Dec. 1927).

III. HARVESTING AND CURING.

The details of time, method of collection and the process of drying for both seeds and stems were studied in this phase of ephedra production. When the plants were placed under cultivation, seed production increased steadily, especially after it was found the stems were perennial. While this promised to materially aid propagation, it also raised the question of how the

seed could best be harvested. Data concerning seeds collected from two plots which were uncut for four seasons are shown in Table V.

TABLE V.

Year.	Stem Age.	Seed Weight.	Date Matured.
1934	1 year	15 Gm.	September
1935	2 year	25 Gm.	August
1936	3 year	40 Gm.	July and Aug.
1937	4 year	720 Gm.	July and Aug.

Ephedra seeds will average about one hundred seeds to the Gm. Besides the very remarkable increase in yield, it was noted that on the older stems seeds matured at an earlier date thereby avoiding all danger from frost.

Since seeds ripen over a long period of time, it is impossible to make one complete and final harvest. Furthermore, the plants are not suited to machine collection for many seeds are borne close to the ground on the lower stems. (See Fig. 3.) As the fruits ripen they fall at the lightest touch except for a very few plants on which they persist for some time. Several methods of collection were attempted such as brushing a screen basket through the plants and using a reel for brushing them back on to a platform but none were successful enough to be recommended as a feasible commercial method. Collection of seeds by hand, therefore, seems the most logical.

The next problem considered was that of curing and threshing. When the fruits are dried they assume a rasin-like consistency and even after months of drying they do not thresh well. Hand threshing mills were tried but the results were quite disappointing.

Since each berry holds only two seeds, some of these were planted and it was found that the seeds germinated equally as well, if not better, than the seeds alone. Presumably the fruit mesocarp held enough moisture to successfully germinate the seed and start the young plant even when the soil was so dry that seeds alone were delayed in sprouting. This perhaps is nature's method of insuring good germination of the self-sown seeds of these dry land plants. The best means of handling ephedra seed is to gather the whole fruits by hand, cure them and then either plant the fruit as it has dried or separate the seeds by hand if desired.

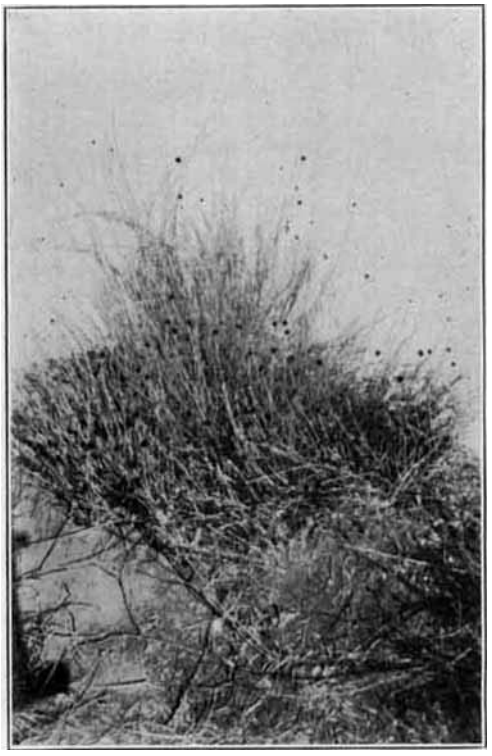

Fig. 3.—*South Dakota Ephedra Sinica.* Ephedra plants are not particularly suited to a machine harvest of the fruits or seeds. Many of the fruits are clustered close to the ground, and when ripe they fall at the slightest touch.

The logical time of year for harvesting ephedra stems is when their alkaloidal content is highest. It has been reported that the ephedrine content is highest in the fall of the year (1) and that the stems should be cut at that time (2). To determine proper time for harvesting, cuttings were made at various dates and subsequently assayed to determine the ephedrine content. A complete record of the harvests and assays for the one- and two-year old stems is contained in a preliminary report published in 1936 (3).

This work was continued until data had been collected for stems matured during four growing seasons. Seed and stem production continued to increase as the stems matured. Data

concerning alkaloid content, date of harvesting and method of curing for three-year stems harvested in 1936 are shown in Table VI.

TABLE VI.

1936 Harvest Dates.	Care.	Assay.
1. September 21st	Sun Cured	0.421%
September 21st	Shade Cured	0.418%
2. September 28th	Sun Cured	0.401%
3. October 7th	Sun Cured	0.416%
4. October 12th	Sun Cured	0.339%
5. October 17th	Sun Cured	0.401%

It is to be noted that the ephedrine content has continued to increase with aging of plants although not as markedly as in the case of the two-year as compared to one-year stems. It is to be noted also that sun-cured stems of the September cuttings contained the highest per cents of ephedrine.

Data for four-year stems harvested in 1937 are shown in Table VII.

TABLE VII.

1937 Harvest Dates.	Care.	Assay.
1. September 25th	Sun Cured	0.740%
September 25th	Shade Cured	0.770%
2. October 5th	Sun Cured	0.740%
October 5th	Shade Cured	0.812%
3. October 9th	Sun Cured	0.764%
October 9th	Shade Cured	0.818%

It is to be noted that the assay of the four-year stems is approximating that of the imported drug and particularly that the ephedrine content is steadily increasing with aging of the plants. Considering the fact that the Chinese plants are growing wild, it is quite likely they too have matured several seasons in order to develop their high ephedrine content. If this is the case there is a good possibility that the American grown drug will eventually equal the imported stems in its ephedrine content.

Cuttings were also made each year of the one-year stems in order to keep informed on any changes which might have occurred. All of these continued to run low in their alkaloid content; about 0.1 per cent. However, it was noticed that in 1937 those one-year stems which were cut from root stock that had not been disturbed for three years showed a distinct increase, up to 0.278 per cent. When the plants are no longer disturbed for propagation purposes, it may prove beneficial to their production of ephedrine.

In corroboration of the earlier findings, this additional information bears out the conclusions that ephedra should be cut in late September or early October, and that sun-curing in the field is a satisfactory means of drying the drug. It cures very slowly and may have to be stored indoors for some time before the drug will powder readily, especially if the season is wet. Stems cured in the shade retained their green color, but the slight difference in the assay was not sufficient to warrant the extra labor involved in handling it in this way.

Getting the stems cut proved the most perplexing of the harvesting problems. The one- and two-year stems were easily cut with an ordinary mower, but by the end of the 1936 growing season, the three-year stems had become so lignified and matted together that they were difficult to handle. Many of the stems were also flattened to the ground due to the extra weight of increased stem production, which would necessitate the use of a mechanical pick-up in front of the sickle bar. Those stems which were uncut would not be lost, however, for they would bud at their nodes the following spring and serve to increase the number of stems produced by the plants the next year. Ephedra is seemingly adapted to such a harvest as is carried out with ordinary farm haying tools, although stem development may eventually necessitate other means of cutting.

SUMMARY AND CONCLUSIONS.

A study was made of the best time of the year for harvesting ephedra seeds and stems and of the methods best suited for their proper curing.

1. The seeds are best collected by hand picking the fruits. After the fruits are dried, the seed can either be separated or the whole fruit can be planted just as it has been cured.

2. The stems should be cut in late September or early October. Sun curing is satisfactory.

3. Farm haying tools seem well adapted to handling this drug by using mowers to cut the stems, allowing them to cure in the sun, and either stacking the stems or baling them for shipment.

4. As the stems mature, they become so lignified it may make other means of cutting them a necessity.

REFERENCES.

(1) Ghosh, T. P., and Krisma S., *Arch. Pharm. Bul.*, 268, 636 (1930).
(2) Youngken, H. W., Textbook of Pharmacognosy, 4th Ed., 85 (1936).
(3) Christensen, B. V., and Hiner, L. D., JOUR. A. PH. A., 25, 969 (1936).

IV. ASSAY[1] AND COMMERCIAL ASPECTS.

Since ephedra is not official, standards and methods of assaying are left to the discretion of the various concerns handling ephedra products. Hence, such firms have developed their own methods for evaluation of the drug. Through the courtesy of one of these firms a recognized commercial assay procedure was supplied and used in obtaining data presented herewith.

In assaying ephedra some peculiarities were encountered, namely,

1. The alkaloid is water soluble (1), and easily decomposed by direct heat.
2. Ephedrine is hygroscopic.
3. Stronger ammonia water in excessive amounts is required to free ephedrine from its salts (2).
4. Time is an important factor in the assay process when chloroform is used in the menstruum. Ephedrine hydrochloride is formed when the alkaloid is allowed to stand or evaporate in this solution (3), thus reducing the total alkaloids as indicated by the final titration.
5. Many of the common alkaloidal precipitants do not give their characteristic reaction with this alkaloid (4).
6. Evaporation to dryness, particularly with heat, is not advisable in evaporating the final ethereal solution prior to titration.
7. A single plant does not constitute a representative sample. Great variation occurs in the alkaloid content of different plants within the same plot. Mix the powder thoroughly before assaying.
8. The alkaloid is confined to the stems.

Unless all of these points are observed in assaying ephedra, discrepancies are certain to result. The following procedure is, therefore, recommended for the determination of total alkaloids in ephedra.

1. Use 10-Gm. samples in a fine powder, accurately weighed with allowance made for the moisture content.
2. Place the powder in a suitable percolator after first wetting the cotton pledget in the bottom with ether, saturate the drug with ether-chloroform menstruum, 4:1, and allow to stand at least five minutes. Add 10 cc. of 28 per cent ammonia water, mix thoroughly and after 15 minutes add an excess of the ether-chloroform menstruum and allow to macerate over night.
3. The next morning pack the drug firmly and percolate at a moderate rate using ether-chloroform menstruum in the same proportion, 4:1. Continue percolation until 300 to 400 cc. of percolate have been collected. For the 10-Gm. samples this always gave complete extraction as indicated by the use of suitable precipitants.

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[1] Acknowledgment to Eli Lilly and Company for the original assay procedure used.

4. Transfer the percolate to a separatory funnel and completely extract the alkaloid by shaking with several portions of 2 per cent sulfuric acid. Filter each portion as drawn off, wash the filter, and then wash the combined acid extract with three 40-cc. portions of ether to remove traces of chloroform which may have carried through.

5. Add a portion of ether to the acid solution, make strongly alkaline with a decided excess of stronger ammonia and completely extract the freed alkaloids with several successive washings of ether as recommended by the U. S. P. XI, page 146. A Palkin-Watkins continuous extraction apparatus was used to good advantage in this step (5). From this point to completion proceed as recommended by the U. S. P. XI for assay of ephedrine salts.

This procedure gave consistent results as evidenced by the uniform figures reported by different workers assaying samples of the same drug.

Another problem considered was that of relative yields of crude material produced in (*a*) growing periods of one year, two years, three years and four years with annual harvests, (*b*) with harvests at the end of one year, at the end of two years, at the end of three years and at the end of four years.

(*a*) With annual harvests, each year shows an increase in yield as indicated in Table VIII.

(*b*) Yields of two-year plants was greater than that of any one annual harvest and approximately equal to that of both annual harvests of the first two years. Yields of three-year and four-year plants continued to increase but the increase in weight from year to year was not constant, *i. e.*, four yearly harvests in the end yielded more crude drug than one cutting at the end of the four years as indicated in Table IX as compared to data in Table VIII.

TABLE VIII.

Year.	Stem Age.	Per Acre Yield.
1934	1 year stems	3,485 pounds
1935	1 year stems	3,502 pounds
1936	1 year stems	3,890 pounds
1937	1 year stems	4,000 pounds

TABLE IX.

Year.	Stem Age.	Per Acre Yield.
1935	2 year stems	6,921 pounds
1936	3 year stems	8,421 pounds
1937	4 year stems	10,101 pounds

Over a four-year period of time four yearly harvests yielded a total of 14,877 pounds of drug per acre, as compared to 10,101 pounds per acre taken as one cutting at the end of four years. However, other factors such as quality of the stems are of importance. Hence, data showing weights harvested, alkaloid content and yield of total alkaloids is given in Table X.

TABLE X.

Year.	Stem Age.	Per Acre Yield.	Assay.	Total Alkaloids.
1933	1 year	3,845 pounds	0.126%	4.84 pounds
1934	1 year	3,845 pounds	0.150%	5.22 pounds
1935	1 year	3,502 pounds	0.153%	5.35 pounds
1936	1 year	3,890 pounds	0.167%	6.49 pounds
1937	1 year	4,000 pounds	0.214%	8.56 pounds
1935	2 year	6,921 pounds	0.366%	25.33 pounds
1936	3 year	8,421 pounds	0.421%	35.45 pounds
1937	4 year	10,101 pounds	0.818%	82.82 pounds

From the above it is apparent that the four-year old stems represent the best prospect for per acre yield of total alkaloids and consequently the best prospect for commercial production of ephedra. Not only is the yield of active principle superior, but it has in its favor the fact that there

is less expense involved in handling one cutting as compared to several. The four-year stems have developed an ephedrine content which should satisfy commercial demand.

Based on estimates received by submitting samples of ephedra from the four-year lot to various buyers, an acre should produce approximately $303.00 worth of ephedra each four years, or an average of $75.75 per year. It should also be considered that:

1. The plants have been continually disturbed for propagation purposes, and have not yet reached their full production capacity.
2. There is positive evidence that the alkaloid content will increase when the plants are left undisturbed.
3. The intention is to grow ephedra on land which at the present time is unproductive, sub-marginal land.

Future prospects for ephedra cultivation appear quite encouraging.

SUMMARY AND CONCLUSIONS.

Yields of ephedra per acre were determined from stems of various ages. These were assayed and data assembled concerning the commercial aspects of South Dakota grown ephedra. The following conclusions were reached.

1. A suitable assay procedure is recommended.
2. Four-year stems represent the best prospect for commercializing ephedra production.
3. While many phases of the problem remain to be studied, South Dakota can produce Ephedra sinica of commercial value, and especially so in case of a national emergency.

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THE PHARMACOLOGY OF SOAPS.*

BY LEROY D. EDWARDS.[1]

The United States Pharmacopœia, eleventh revision, does not require, as did former editions, that the official soap (Sapo Durus) be made from olive oil. This soap may now be prepared from any oil or mixture of oils so long as it meets several chemical and physical tests as described in the U. S. P. The reasons[1] given for this change were that soaps possessing similar chemical characteristics to a soap made from olive oil may be made from mixtures of various oils, and that there are no chemical means to differentiate between such soaps. This change may be questioned on the ground that soaps made from various oils or mixtures of oils may possess, as determined by our present day methods, chemical and physical properties similar to those of an olive oil soap but may, at the same time, show different physiological reactions, *f. i.*, irritant effect upon the skin.

The following studies of the action of soaps on red blood cells and earthworms are offered as an approach to this problem.

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[1] From the Department of Pharmacology, School of Medicine, and the School of Pharmacy, Western Reserve University.