1925

A Chemical and Morphological Study of Grindelia Squarrosa (Pursh) Dunal

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A CHEMICAL AND MORPHOLOGICAL STUDY
OF
GRINDELIA SQUARROSA (PURSH) DUNAL.

By

Marcus A. Chase, B. S. 1921

A Thesis

Submitted in Partial Fulfillment of the Requirements

For the Degree of Master of Science

In Pharmaceutical Chemistry

To the Faculty

of

The South Dakota State College

of

Agriculture and Mechanic Arts

June 1925

Flowering Plant of Grindelia squarrosa (Pursh) Dunal.

Typical Specimen of tall, sparingly

branched variety.

Frontispiece.


MEDICINAL AND POISONOUS PLANT INVESTIGATIONS
SOUTH DAKOTA SCHOOL OF PHARMACY

Flowering Plant of *Grindelia squarrosa* (Pursh) Dunal.

Typical Specimen of low, diffusely

branched variety.

Frontispiece.

INTRODUCTION

A species of Grindelia known as Gum, Rosin or Tar weed, is of common occurrence on dry banks and sandy soils in various parts of South Dakota. During dry seasons it attains such a dense growth in closely cropped pastures that horses feeding in them have their heads and manes covered with a black tarry-like substance, and their fetlocks collect fairly large balls of this tarry mass. In dry years the development of the weed is so rapid that the grass in a closely cropped pasture may be nearly exterminated during a single season. A pasture may seem to be entirely freed from Grindelia for several rainy years when one season of drought will cause it to develop a thick stand. It yields to cultivation readily, attaining the heighth of three feet.

It has never been noticed by the writer in virgin sod, and early settlers of fifty or more years ago, do not remember having seen it at that time. This leads to an interesting question. How did Grindelia become naturalized in South Dakota? It has been observed that this drought resisting plant usually follows the course of rivers. Perhaps it entered South Dakota in that manner or admixed with grass or clover seed. The hardy nature of the plant may be attributed to its resinous nature.

Pammel in his Manual of Poisonous Plants states that animals do not like it, so that cases of animal poisoning by Grindelia are quite rare.

Because of the common occurrence of this drug plant in South Dakota, it was deemed advisable to make a study of same from various standpoints, to determine whether or not it was one of the three species of Grindelia as recognized by the Ninth Decennial Revision of the United States Pharmacopoeia, and if so, the commercial possibilities that its collection and marketing offered, as well as to make a chemical and morphological study of the plant.

For reasons as stated later under the title of "Synonymy" the species was determined to be Grindelia squarrosa (Pursh) Dunal, which places it within the U. S. P. IX requirements, the latter designating G. camporum Green; G. cuneifolia Nuttall and G. squarrosa (Pursh) Dunal.

Replies received in response to inquiries concerning its commercial possibilities have led to the general conclusion that there is very little, if any demand for the South Dakota drug. A typical letter is here included to show the opinion of one competent to advise in this matter.

THE WM. S. MERRELL COMPANY
Manufacturing Pharmacists
Founded 1828
Home Offices and Laboratories, Cincinnati, U. S. A.

February 20, 1925

Professor Anton Hogstad, Jr.
Brookings, South Dakota

My dear Hogstad:

The collection of crude drugs is almost entirely in the hands of farmers in their off seasons, or poor

mountaineers and other people who are willing to work for very low pay. The only hopes of making any profit is to find a fairly abundant supply of some plant that is in general quite rare, or of finding some of the cheaper drugs in stands so free from other plants that rapid and cheap methods of gathering can be employed. For example, one might find a big clump of mandrake so free from other plants that he could plow the roots up.

Pulsatilla is selling at 12¢ New York which means that it must be sold from 6 to 8¢ at Brookings in order to compete. This low return makes profitable handling of the domestic herb out of the question.

Grindelia according to our purchasing records has never had an extended price advance, indicating that the available supply is far in excess of the demand. Present prices are around 8¢ New York. I believe it is to be included at the present time in carload shipments of Cascara and Berberis from the West Coast, or sent through the canal. Unless this plant is extremely plentiful in South Dakota it would seem that the low values that have always obtained for it will prevent its exploitation for profit in new territory.

Of course shipments could be made direct to Middle West drug manufacturers, but my impression is that there are few drugs native to South Dakota that are found there in commercial quantities, and certainly if Pulsatilla and Grindelia are the most important of these, it would seem that sufficient volume would be lacking to justify the expense of doing business.

The mountains of North Carolina furnish most of our domestic drugs, except of course, such as Cascara, Berberis and Echinacea, which have a restricted habitat.

I looked into the subject while at the A. Ph. A. Meeting in 1923 in Asheville which is the headquarters of two of the largest wholesalers, S. B. Penick & Company, and J. O. McGuire & Company, 117 North Lexington Avenue, Asheville.

These dealers receive parcels of dried drugs by parcel post from all over the south. They come in every conceivable form and size of container. Generally they are in bags the size varying from 1 to 100 pounds.

The collectors around Asheville some of whom I interviewed are nearly all "Hill Billies" or "Poor Whites". They collect drugs in the time left from their regular crops and very few devote a great deal of time to it, only their spare time, as the returns are very small.

I suggest that you write to the firms named and to Prof. E. V. Howell, Chapel Hill, N. C. for further information on the subject.

Yours cordially,

Caswell A. Mayo (signed)

Dr. Caswell A. Mayo

SYNONYMY

The genus Grindelia includes some twenty-five species and about fifty varieties, six or eight of which are found in South America; especially in the more southerly countries, and the remainder in North America; particularly in the United States west of the Mississippi river, in Mexico and in southern Canada.

The material used for the work in hand was determined to be Grindelia squarrosa (Pursh) Dunal. It was collected on the abandoned right-of-way about two miles south of Brookings, South Dakota, and answers the following description taken from various sources.

Grindelia squarrosa (Pursh) Dunal is a common plant on the prairies and dry banks of the western part of the United States. It has been reported as occurring from Saskatchewan to Minnesota, Texas and California. It is a glabrous, erect, branching herb having linear, oblong or lanceolate leaves, which are more or less clasping at the base, and sharply spinulose dentate. It is especially characterized by the bracts of the involucre being Linear lanceolate, subulate tipped and spreading or squarrose at the summit giving the species its name. The achenes are truncate, those of the outer flower being usually thicker. The pappus consists of two to four awns. Literature cited states two to three awns, but the writer has noted four in a few cases.

The genus name was given in 1807 by Willd in

honor of Professor H. von Grindel of Dorpat and Riga, who had carried on an extensive study of the poisoning due to Rhus Toxicodendron. The species was first determined in 1814 by Pursh, who gave it the name Donia squarrosa. It was not until 1836 that Dunal classified it in the genus named by Willd, thus giving the name Grindelia squarrosa (Pursh) Dunal.

Other species or varieties falling within the present understanding of the term are Grindelia grandiflora Hook 1852; Grindelia nuda Wood 1878; and Grindelia squarrosa (Pursh) Dunal, so that the present investigation seems fully justified.

The common synonyms of Grindelia species are: Hardy Grindelia, Yellow Tar Weed, Gum Plant, and Wild Sunflower. In South Dakota it is commonly called Rosin Weed or Pitch Weed.

HISTORICAL

The Jesuit and Franciscan monks were acquainted with the medicinal properties of Grindelia species as early as the first half of the eighteenth century. They learned of its use from the Indians of the California littoral with whom its use was traditional. It was used in poultices and as a fluidextract in the treatment of snake bites, insect bites, and poisoning produced by Rhus Toxicodendron. It also found use in cases of renal nephritis but often aggravated that condition if used in too large amounts, due to its irritating properties. Being strongly antispasmodic in action it enjoyed popularity as a remedy for asthma. For this purpose it was mixed with potassium nitrate to produce a smoking powder which was used in the form of cigarettes.

In 1863, its medicinal properties were first mentioned in an official communication by Dr. C. A. Canfield of Monterery, California, in which he emphasized its use as a specific for Rhus Toxicodendron poisoning. In 1875, Mr. James G. Steele, a pharmacist in the city of San Francisco contributed a paper to the American Pharmaceutical Association telling of its specific action in Rhus poisoning, and about the same time Dr. W. P. Gibbons of the same city, read a paper before the American Medical Association describing its use in cases of chronic Rhus poisoning which had come under his observation.

It was not until 1880, however, that the species Grindelia robusta Nuttall, became official in the United States Pharmacopoeia. About this time Parke Davis and Company organized its gathering and distribution and to them may be attributed its general introduction into the drug trade. The Pharmacopoeia of 1890 as well as that of 1900 included the species Grindelia squarrosa (Pursh) Dunal in addition to Grindelia robusta Nuttall.

Because Grindelia robusta as found in commerce is of questionable authenticity, owing to the very close resemblance it bears to other species of Grindelia and because of its own scarcity it was dropped from the Pharmacopoeia in the Ninth Decennial Revision, the varieties mentioned there being: Grindelia camporum Green; G. cuneifolia Nuttall; Grindelia squarrosa (Pursh) Dunal.

The Tenth Decennial Revision of the Pharmacopoeia will not recognize any species of Grindelia.

ACTION AND THERAPEUTICS

Grindelia possesses the following medicinal properties: Cardiac sedative, expectorant, antispasmodic, tonic, stomachic, diuretic, relaxes muscular coat of bronchial tubes; large doses producing narcosis, dilated pupils and impaired powers of locomotion. It increases frequency of urination. The general systemic action is similar to that of Conium, being a marked motor depressant. Cases of poisoning should be treated similar to that of Conium.

It is used in solution or as a poultice for the following disorders: Asthma, bronchitis, whooping cough, catarrh of the bladder and poisoning by Rhus Toxicodendron. It is eliminated by the bronchial mucous membrane and the kidneys, stimulating both, the latter sometimes to the extent of irritation.

CHEMICAL STUDIES

Although, as stated before in the historical discussion, the drug has been used for a great number of years, it was not until the work done by Power and Tutin was presented to the American Pharmaceutical Association in 1905 and again in 1907, that a definite chemical examination of Grindelia species had been carried through on a sufficiently large scale to justify acceptance of the results. For that reason previous studies will not be discussed with the fulness that this later chemical study will receive. These previous discussions show so little agreement, that it is interesting to take them up in relation to the findings of Power and Tutin.

It is generally agreed, that a mixture of resins is the chief constituent, and that there is a quantity of volatile oil present to which Haensel has attributed conium-like properties. A number of investigators report the presence of a glucoside or glucosides, but there is an entire disagreement and very little positive evidence to substantiate the statements. Tunmann, testing in situ, was able to localize what seemed to be a glucoside of a saponin-like nature, but was careful to state that the test was not positive. As is to be sure with resin separation, the various substances present are difficult to obtain in a pure form. No doubt this accounts for the lack of agreement which are encountered in reports of various investigators. H. Fischer and

von Greshoff announce the separation of an alkaloid Grindeline, the existence of which has been generally denied by other investigators. Clark reports the discovery of a saponin or saponin-like substance which he has named Grindelin, and from which he says the resin is formed by decomposition.

Fischer in addition to claiming to have found an alkaloid, announces the separation of a crystallizable acid, soluble in water, alcohol and ether, which he has termed robustic acid. Neither of these substances were sufficiently characterized. Shneegans stated that he found two glucosides having the characteristics of saponins, one of which was precipitated by the normal acetate, and the other by the basic acetate of lead. On the other hand, he found that the evidence of the presence of an alkaloid was so slight as to lead him to doubt the presence of such a substance. The above will show the lack of agreement encountered in literature cited.

In making a complete report of the work of Tutin and Power, it is well to remember that the material used by them was that of Grindelia camporum Green, as determined by Dr. Willis L. Jepson, and that the drug was obtained in an original bale from California; being of good quality and in every respect complying with the requirements as set forth in the United States Pharmacopoeia. Power and Tutin employed some 207 pounds of the drug, finely ground, and then subjected to extraction in a suitable apparatus, with hot alcohol. This extract was

evaporated to 70 1/2 pounds, representing 34 percent of the weight of the drug. After being subjected to an additional heating in a water oven, the residue was still further reduced in amount, yielding 29 6/10 percent.

Steam distillation yielded a volatile oil representing 0.068 percent of the drug. It gave an acid reaction and was shown to contain formic and butyric acids by proper tests. The water extract from the above steam distillate was treated in such a manner as to separate the material contained in solution and to this material were applied tests for saponins, with negative results. These facts led the investigators to the conclusion that there were no saponins present, as reported by Clark and Schneegans. (This conclusion may be mistaken since the passing of steam through the resin may have been sufficient to hydrolyze any saponin present into its cleavage products.)

The above extract yielded a characteristic osazone, with a melting point of 205-206 C, and was laevorotatory thus apparently being laevo-glucose. The writer was able to obtain the above mentioned osazone and found that the solution of the glucose was laevorotatory, thus confirming for Grindelia squarrosa what Power and Tutin found to be true for G. camporum.

Upon heating the alcohol extract with alcoholic KOH a large amount of ammonia was evolved, which was later shown to be due to the decomposition of the chlorophyll contained in the extract. The alcohol was

distilled off and the residue extracted with ether. Upon concentration this ether yielded a yellow crystalline substance which upon purification and quantitative analysis was shown to be $C_{31}H_{64}$ or Hentricontane, a hydrocarbon already isolated from several other sources. From the mother liquors of the above hydrocarbon a new phytosterol with a melting point of 166 C was obtained.

The portion of the Grindelia resins which is soluble in petroleum ether, consists to a large extent of a complex mixture of liquid acids. These acids are for the most part optically active, unsaturated cyclic compounds. Some of them are oxy-acids and appear to contain benzene nuclei. A very small amount of cerotic acid and apparently a trace of palmitic acid are also present in the extract from Grindelia.

In a summarized statement Power and Tutin make particular mention of the fact that they found no alkaloids or saponins.

The first attempt by the writer at extraction of the South Dakota herb was with an apparatus diagrammatically shown in Plate XI, Fig A. A glance at the diagram makes clear immediately that it is an adaptation of the Soxhlet extractor. A sufficient quantity of solvent was introduced through the condenser to discharge the siphon, and in addition, to fill the percolator nearly to the point of discharge a second time. This provided sufficient solvent to prevent the extract from being heated to too high a temperature. The cork stoppers were mercury sealed with the aid of adhesive tape. It was found after the second discharge of the siphon that sufficient water extract had been forced from the herb to form a sticky layer in the bottom of the percolator and siphon to prevent the solvent from discharging.

The need of a new type of extractor for the work in hand led to the preparation of the type of apparatus shown in Plate XI, Fig. B. in which the discharge was directly into the flask and was regulated by a stop-cock. This necessitated the constant watchfulness of someone and prevented night extraction, but on the whole proved quite satisfactory. With solvents other than ether, which depends so much on heat of the room for rapidity of extraction, it was found possible to set the stop-cock in such a manner as to retain the discharge at the same rate as the intake of the solvent.

Ether was used to preserve the material in each case and consequently was used as the first solvent in the continuous extraction. It was found to remove about 1/3 of the resin content. Experiment showed warm ethyl alcohol to be the complete solvent of the resins of Grindelia, so that it was placed last on the list of solvents for the continuous extraction in order to remove any soluble matter not previously extracted. After ether, wood alcohol was used, the chloroform, benzine and finally ethyl alcohol.

The accompanying table shows the percentage of resin removed by each solvent from the Sample A I, which was the carefully separated, fully developed, flowering heads, in which many heads were fully matured. This material was collected August 29, 1924, about two miles south of Brookings, South Dakota, on the Medary road, where the abandoned right-of-way runs parallel to the highway. It was placed while fresh into ether in a glass covered quart jar, and maintained with total water content. A portion of the material was assayed for moisture by the oven (105 C) and also by the xylene method. The former method showed the drug to contain 60 percent while the latter 50 percent of moisture.

(Xylene Method for Moisture Determination)

Reference: Dean, Arthur L., Forest Service Circular 134.

Dean has termed the method as an adaptation of the Marcusson' method for determination of water in lubricating oils. The method is as follows:

Ten to twenty five grams of creosoted wood in in the form of borings, turnings, sawdust or similar material is quickly weighed and transferred to a 250 cc. Erlenmeyer flask and to which is added 75 cc. of water-saturated xylene. A paraffin bath of convenient size is filled 2/3 full of paraffin or some lubricating oil. The bath is heated and distillation continued until the distillate comes over in clear drops. The condenser should be washed with xylene water before another determination is run. After standing, the distillate separates and the amount of water may be read directly from the specially-graduated funnel. The distillation should be very slow so as to allow for the complete volatilization of the moisture present. These determinations are apt to run 1/10 of 1 percent too low.

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The ether extract of Batch I B yielded 30 grams from a 250 gram sample, being exactly the same proportional amount that had been obtained from Batch I A. These samples differed only in being the mature flowers, Batch I A and the freshly opened flowerheads, Batch I B.

This similarity of results lead the writer to deduce that the time of gathering the herb would play very little part in the amount of resin produced by the drug.

The mixed flower heads yielded 25 grams of ether extract for 250 grams of the wet drug, which was two percent.less than the amount yielded by the mature

and freshly-opened flowers.

A representative sample of the undried drug, assaying 50 percent moisture (Xylene method), yielded 50 grams total extract or the equivalent of 100 grams of anhydrous drug, being 40 percent total resin content for the water-free drug. This finding places the resin content above that obtained by Power and Tutin for Grindelia camporum (29.5 percent), providing their calculations were based on the anhydrous drug, which they do not state.

General resin tests as outlined by Tunmann in his article on Grindelia robusta, were found to be applicable in the case of G. squarrosa. Vanillin and Hydrochloric acid gave a bright yellow color with the resin of the leaf hairs, both of the ascidium-shaped glandular and club-shaped glandular hairs, but did not affect the resin of the secretion reservoirs. Sulphuric acid and alcohol (1:1) does not change the color of the resins located in the reservoirs, while that of the hairs was changed to a yellow coloration. Addition of ferric chloride changes the color to a brown or blue-brown (Hanausek's saponin reaction). The latter shows that there may be a saponin present, in which case it is localized in the glandular hairs.

Other results as noted by the writer may be summarized by the statement that the extract from any portion of the drug was resinous in appearance. The roots yielded the least and the flowers the greatest amount of extracted materials.

EXTRACTION OF BATCH 1 A

500 GRAMS

Solvent	Ether	CH_3OH	$CHCL_3$	Benzine	C_2H_5OH	Total
Wt. of extract	60	25	20	10	10	125
% Ext. in wet drug	12	5	4	2	2	25
% Ext. in dry drug	24	10	8	4	4	50
Color	Yellow brown	Dirty brown	Orange brown	Caramel brown	Dark brown	
Odor	Natural	To-bacco	Molas-ses	Naus-eating	Licorice	
Taste	Burning	Burn-ing	Naus-eating	Burn-ing	Licorice	
Hardness	Plastic solid	Semi-solid	Solid	Plas-tic mass	Plastic solid	

the most part raphides.

The tap roots are from 0.5 to 1 cm. in diameter and are rather short, considering that they are biennial or perennial in nature.

STEM STRUCTURE

The structure of the stem agrees with that of the root for the most part, except for the fact that there is always an endodermal layer lying close to the outer layer of bast fibers, This endodermal ring is only one cell in thickness, except at times where it broadens between the bundles of bast fibers.

Lying just outside of this endodermal layer is that of the cortical parenchyma area, from 5 to 10 cells in thickness. The first and second layers of this area are often broken down or pushed back from the endodermal layer, in such a manner as to allow for the formation of a resin depository. (Plates VIII, IX and X). Plates VIII and X represent flowering stems while Plate IX is that of a transverse section of the main stem.

The resin ducts of the stem as a general rule, become much smaller upon approaching the vicinity of the root. The resin ducts are not continuous tubes, extending from the flowers and leaves down through the stem to the roots, but are in the nature of biconvex reservoirs. Near the upper extremities of the stem the resin ducts are so arranged that there is one duct opposite each fibrovascular bundle, but such arrangement however is not constant. The resin contained within these ducts appears

to have had its origin in the distinct endodermal area, but data at hand does not warrant a definite statement to this effect.

Adjacent to and outside of the cortex is a thick walled epidermal layer, in which are interspersed occasional stomata. A transverse section of the stem exhibits numerous ridges on the otherwise quite cylindrical stem. The stems vary from 0.2 to 1 cm. in diameter.

LEAF STRUCTURE

The leaves are tapering spatulate, with serrated wavy margins and sessile bases. They vary greatly in size. Near the flower head where they are smallest, they are 1 cm. in length and 0.5 cm. broad at the base, tapering to 0.4 cm. at the narrowest portion. The measurements are in the same proportion when they reach the size of 5.5 cm. in length, being 2.5 cm. broad at the base and 2 cm. at the narrowest portion.

A view of either surface shows well defined green areas surrounded by primary and secondary veins, consisting of heavy collenchymatous cells. The green areas are dotted with large stomata, while on the white veins frequently occur large multicellular glandular hairs, which are located in the indentations of the surface structure.

The leaves of the seedlings are covered with small club-shaped glandular and non-glandular hairs, which seem to disappear upon growth of the leaf. A transverse section through the leaf exhibits large palisade

cells with numerous crystalline bodies scattered throughout and invariably a large inulin vacuole, the latter responding to the test for inulin (Tunmann, D. D. Pharm. Ges. 1910, p. 577). The test is as follows:

Resorcinol 0.1 gram, ethyl alcohol 5 cc., HCl 5 cc. A few drops of this solution are added to the material on the slide, the slide then carefully heated on a water bath. The vacuoles assume a beautiful red color, which gradually changes to a brown on standing.

The secondary veins in transverse section show resin-secreting ducts, the lining of which consists of resin-secreting cells, with an occasional papilla. The resin as noted in these ducts was of a bright green color. This resin does not appear to be of the same nature as that produced in the superficial hairs, as they respond differently to microchemical tests. It has been noted that these ducts do not continue into the primary veins (Plates I and II). A careful study of the photomicrograph discloses no secretion areas nor even the trace of a duct. Tunmann shows that for Grindelia robusta the midrib contains resin ducts. The writer was unable to locate ducts of this nature in G. squarrosa, even though many leaves were sectioned from end to end.

FLOWER HEAD STRUCTURE

The torus of the flowering head, shown in longitudinal section (Plate VI) varies from 0.7 to 1.5 cm. in diameter and in depth from 0.3 dm. to 0.6 cm. In the bud, the bracts, which are elliptical in transverse section,

are quite numerous covering the entire torus, while in the development of the flowering head, the bracts are pushed back from the top and the yellow ray flowers appear as closely studded upright cylinders. The latter gradually open to give the plant an appearance to which may be attributed the common name of wild sunflower. The average length of the ray flowers is about 1.5 cm., the yellow corolla portion being about 1 cm. long.

The fully developed seed is about 0.1 cm. in diameter and 0.2 cm. long. At the point of attachment of the corolla with the seed or ovary, there are from two to four awns and numerous club-shaped glandular hairs. The awns are about equal in length with that of the seed, on the edges of which near the base are a few glandular hairs similar to those found at the point of attachment of the corolla and the seed. Non-glandular hairs were noted to be present higher up on the awns.

The corolla is veined, being traversed by 7 to 9 light colored veins. There are five anthers carrying a decided excess of pollen. The pollen grains are sperical with numerous small promentories on their surfaces.

The stigma is two lobed and is covered with small hair-like resinous protuberances. The tube flower is similar except that the corolla is divided into five petals. The tube flower averages 0.7 cm. in length. The bracts are 0.6 cm. long, lanceolate and somewhat flattened. They are densely covered on their outer surfaces with multicellular glandular hairs, some of which rise above the surface, others of which are indented. Plate VII figure D shows these hairs in superficial and side views

The transverse section shows five bundles with a resin duct on the outer edge of each. The structure is of a heavy collenchymatous nature with a large number of palisade-like cells scattered between. These palisade cells are spherical in nature.

The torus in longitudinal section exhibits numerous resin ducts, the latter occurring outside of the endodermal layer, similar to that of the structure of the stem. These ducts are unusually quite large and contain an abundance of resin. The stem directly beneath the flowering head is composed largely of collenchyma cells and with very small tapering fibrovascular bundles. The large torus resin ducts descend for a short distance into the stem, in the manner indicated under the description of the stem structure.

SUMMARY

1. A historical review has been included dealing with the use by the Indians and Monks and also the introduction of the drug into the drug trade and medical practice.
2. The quantitative determination of the resinous substances as extracted by a series of solvents from the anhydrous drug constitutes the major portion of the chemical study. Ether yielded 24 percent; methyl alcohol 10 percent; chloroform 8 percent; benzine 4 percent; and ethyl alcohol 4 percent making a total of 50 percent of total extract.
3. Notes are included dealing with the physical properties of these various extractives.
4. The fresh drug has been shown to contain 50 percent of moisture (xylene method) and 60 percent (oven, 105C).
5. Particular attention has been devoted to the study of the resin ducts and reservoirs throughout the entire plant. Special emphasis has been placed upon the reservoirs present in the base of the torus.
6. A study was also made of the glandular hairs. In this connection it has been noted that the incolucre bracts were densely covered. The hairs are also present on the ray and tubular florets, being located at the base of the corolla and on the awns. In addition they were also found to be present on the leaves (both surfaces).
7. A histological description (with drawings) of the various plant organs has been presented.

8. The extensive work of Power and Tutin dealing with the chemistry of Grindelia has been reviewed as well as the morphological treatise by Tunmann, which was translated in its entirety from German.

9. The commercial possibilities of this South Dakota drug have been investigated. They appear to be slight, as shown by a letter from one who, no doubt, is capable of reporting on this matter.

ACKNOWLEDGMENT

To Dean Earl R. Serles of the Division of Pharmacy is due special thanks for placing the facilities of the special research laboratory of the Division at the complete disposal of the writer. Acknowledgment is due the Philadelphia College of Pharmacy Library for the loan of special bibliographical material, without which the progress of the work would have been severely handicapped. A wider field was opened to the research by the translation of special articles from the German by Miss Jane Mullenbach of the English Department.

For encouragement, suggestion, criticism and a keen interest in every step of the undertaking the writer wishes to express a deep sense of appreciation to Anton Hogstad Jr. under whose guidance the work was attempted.

POSSIBILITIES FOR FURTHER RESEARCH WITH SOUTH DAKOTA GRINDELIA

Problems not within the scope of this paper presented themselves constantly throughout the progress of the work.

Because it is almost impossible to devise a chemical assay for the resin of Grindelia owing to its complex nature it would be of undoubted value to find some biological assay. To test its specific action in the case of Rhus poisoning, rabbits might be chosen due to their more sensitive skin. The hair from certain areas might be shaved off and a standard Rhus extract applied to the area in such a way as to produce the symptoms of Rhus poisoning. Grindelia could then be used in counteracting this condition and a basis for standardization established. The property of renal stimulation could be determined on some standardized animal quite easily. Antispasmodic action would be almost impossible to determine.

The evident physical differences which exist between the extracts removed by various solvents would raise a question concerning therapeutic properties of the several extracts. It is quite possible that the different action might be isolated in the different extracts.

J. Uri. Lloyd has raised an interesting point in his study of the therapeutic qualities of various Grindelia species. This study might well be extended to

include varieties and even races of plants found in specific localities. It would be of great interest to know if resin properties are materially changed by soil variation as well as climatic differences.

Commercial utilization of resins in other ways than as medicinal preparations, e. g. as varnis and dye bases; would bear extensive investigation. A few experiments conducted by the writer indicated that there might be produced from the resin an excellent varnish resin. There might also be produced various dye bases.

Pharmaceutical studies might reveal a means of combining Grindelia resin in such a manner with other bases that an elegant and pleasing proprietary preparation would be produced. This would win for this South Dakota drug the popular esteem that it justly deserves.

It would be of great morphological interest to follow through the secretion and deposition of resin from the seedling plant to the time of flowering which in most cases would be two years. This might reveal various physiological facts which could be utilized in the study of other resin production.

Where the weed grows in overabundance it might be of value to determine means of utilizing it as fuel. This could be accomplished by grinding it while green and pressing it immediately into bricks which could be subsequently dried and made use of as fuel. This rising material would afford an excellent smoke screen in case of frost.

PLATE I

Transverse section Midrib of Leaf near apex.

Ep, Epidermis; Pal, Palisade cells; Coll, Collenchyma; Scler, Sclerenchyma; Sv, Sieve; Tr, Tracheae.

A Chemical and Morphological Study of Grindelia squarrosa (Pursh.) Dunal.

PLATE I

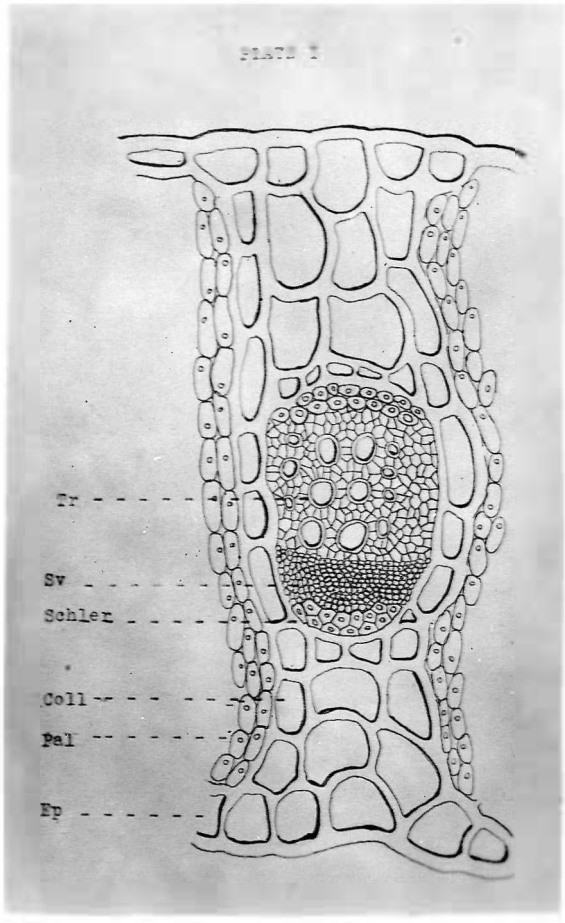

PLATE II

Transverse section Midrib of Leaf near base.

St, Stoma; Ep, Epidermis; Pal, Palisade; Tr, Tracheae; Sv, Sieve; Scler, Sclerenchyma; Coll, Collenchyma.

A Chemical and Morphological Study of Grindelia squarrosa (Pursh.) Dunal.

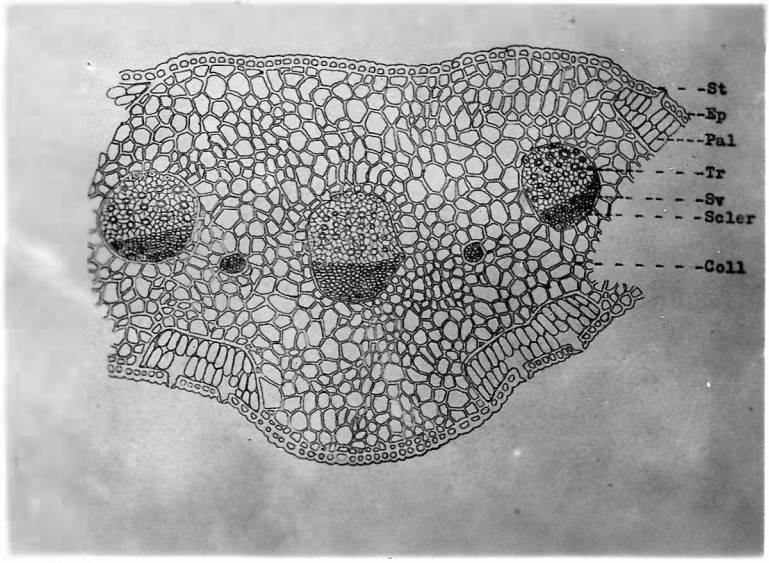
St
Ep
Pal
Tr
Sv
Scler
Coll

PLATE III

Transverse section Secondary Leaf Vein

Ep, Epidermis; Coll, Collenchyma; Pap, Papilla; Res, Resin secretion; Sec, Secretion cells.

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PLATE III

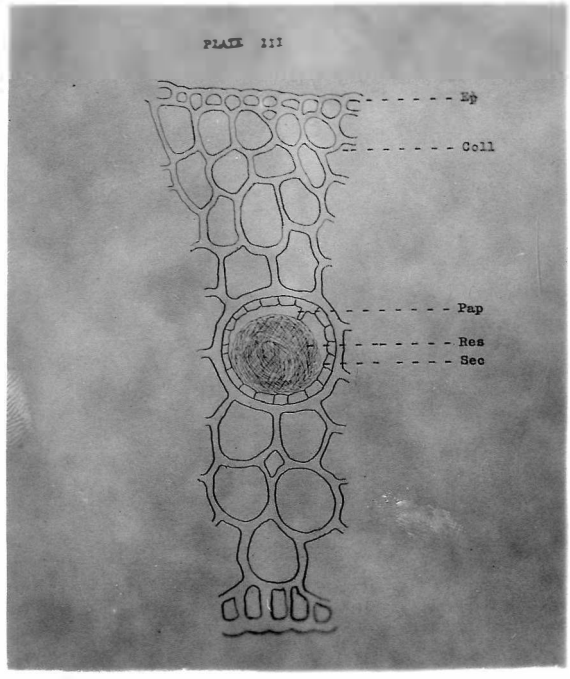

PLATE IV

A:- Upper epidermis of leaf (surface view)

B:- Upper epidermis of leaf (transverse view)

St, Stoma; Ep, Epidermis; Pal, Palisade cells.

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(Pursh.) Dunal.

PLATE IV

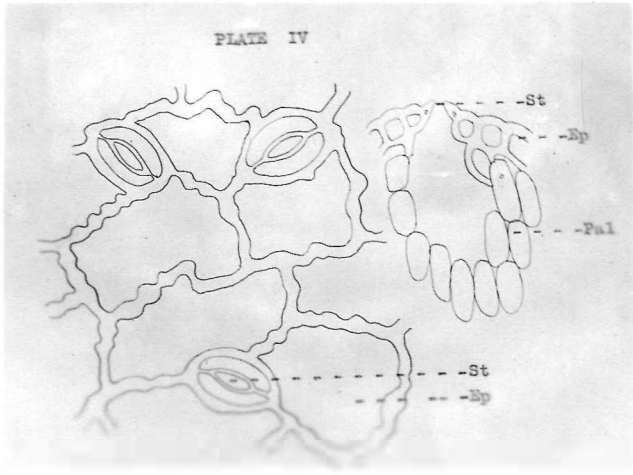

PLATE V

Transverse Section Involucre Bract

GH, Glandular Hair; Ep, Epidermis; Pal, Palisade Cells; Res, Resin Duct; Coll, Collenchyma.

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PLATE V

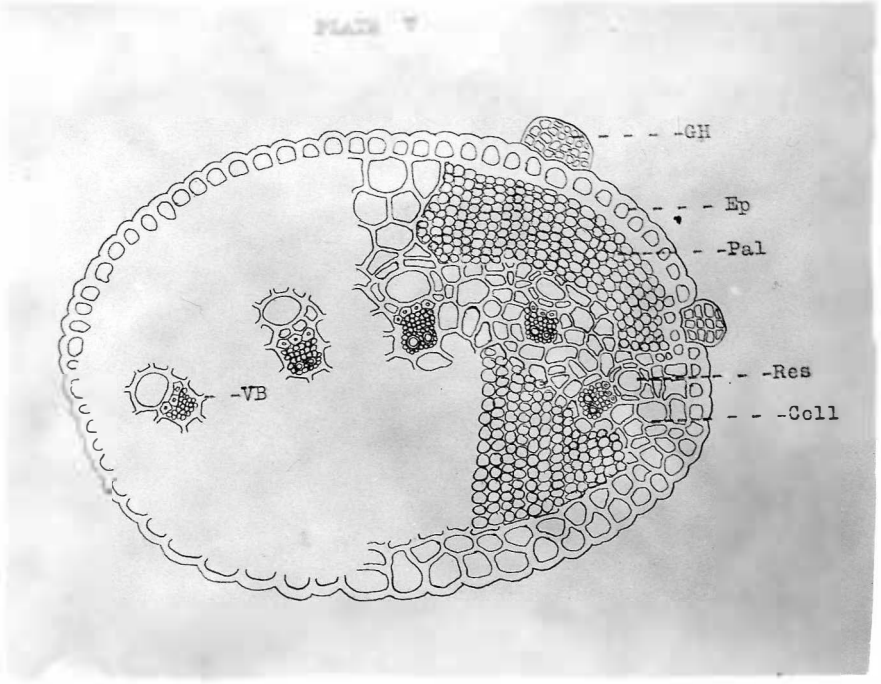

PLATE VI

Longitudinal Section through Torus.

RF, Ray Flower; TF, Tube Flower; Br, Bract;
Res, Resin Duct; VB, Fibrovascular Bundles.

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(Pursh) Dunal.

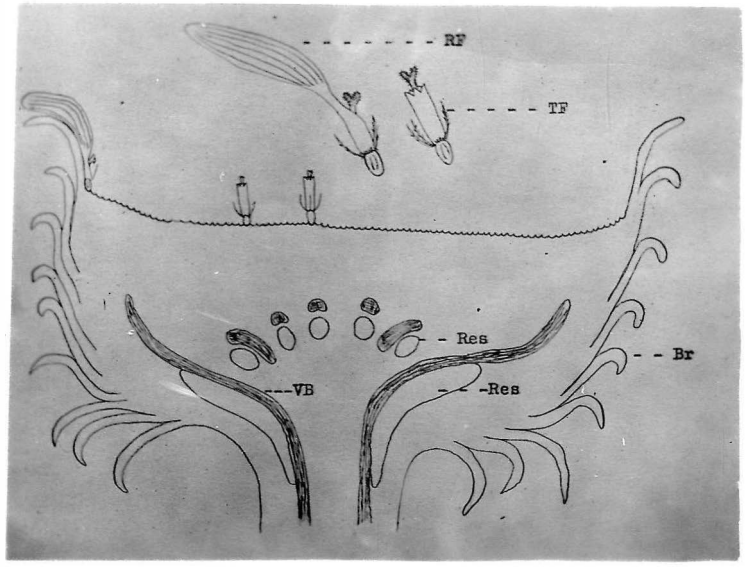
RF
TF
Res
Br
VB
Res

PLATE VII

Types of Glandular Hairs.

A, Hairs occurring on awn; B, Hairs from base of corolla; C, Multicellular hair from leaf; D, Multicellular hair from involucre bract.

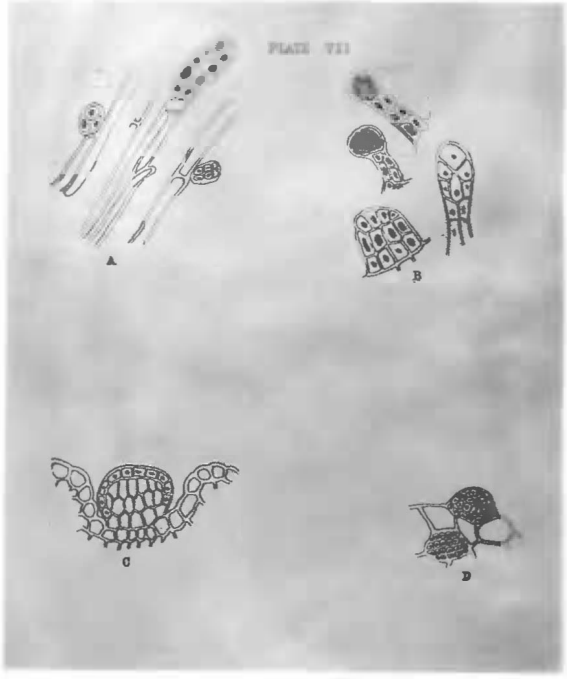
PLATE VII
A
B
C
D

PLATE VIII

Diagramatic Transverse Section through Flowering Stem.

Res, Resin Duct; End, Endodermal Layer; FVB, Fibrovascular Bundle.

PLATE VIII

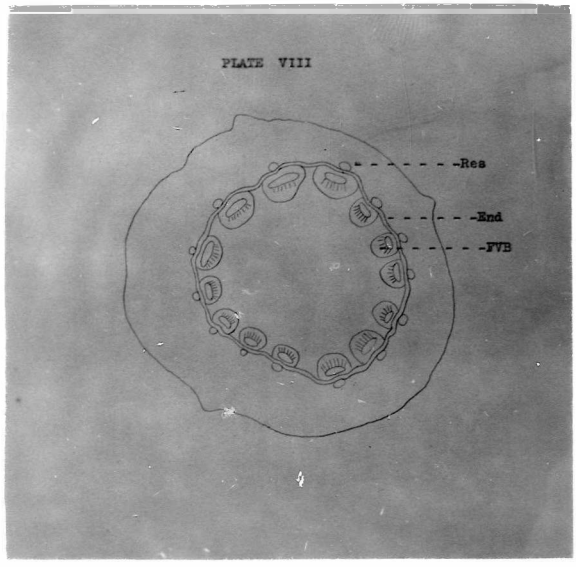

PLATE IX

Portion of Transverse Section through Main Stem.

St, Stoma; Ep, Epidermis; Par, Parenchyma; Res, Resin Duct; End, Endodermal Layer; BF, Bast Fibers; Sv, Sieve; Cmb, Cambium Layer; WF, Wood Fibers; Tr, Tracheae; P, Pith.

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PLATE IX

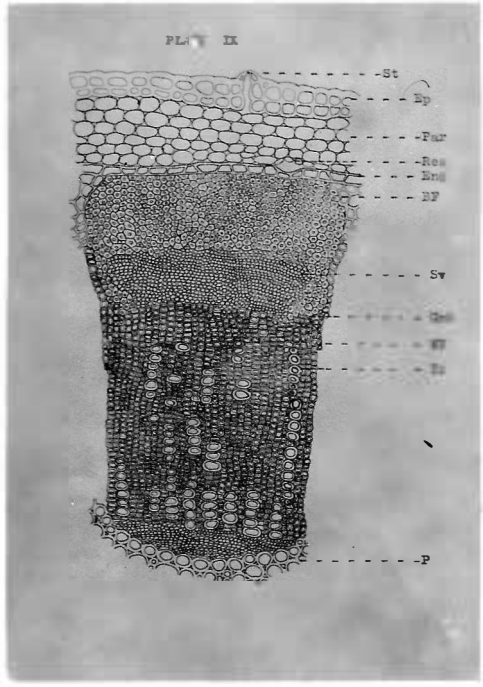


PLATE X

Composite Transverse and Longitudinal Section through Flowering Stem.

Ep, Epidermal Layer; Coll, Collenchyma;
Res, Resin Duct; End, Endodermal Layer:
BF, Bast Fibers; Sv, Sieve; Cmb, Cambium;
WF, Wood Fibers; Tr, Tracheae; P, Pith.

PLATE X

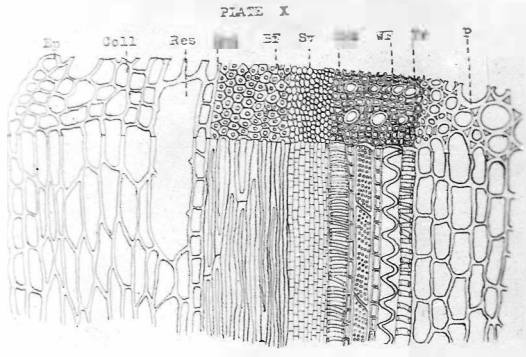
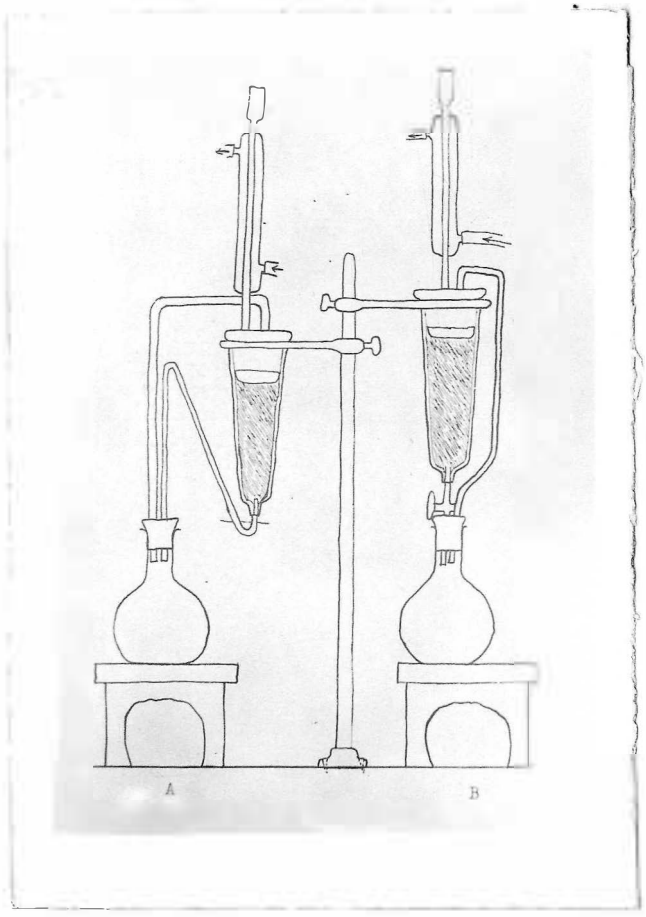


PLATE XI

Extraction Apparatus.

A, First Extractor Used (Siphon)

B, Second Extractor Used (Direct)


A
B

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