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Miscellaneous Series # 196

# REPORT OF THE RUBBER-CROP PRODUCTION COMMITTEE* ON PLANTS GROWN AND TESTED AS A SOURCE OF RUBBER DURING 1942

Misc. Series Paper No. 196

Colorado Agricultural Experiment Station
Colorado State College
Fort Collins, Colo.

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## Guayule (Parthenium argentatum)

Considerable interest was created in the spring of 1942 in the Guayule plant as a source of rubber. While the native range of the plant is south of the Colorado border, inquiries from various sections of the state presented the problem - "Will guayule plants grow and survive the winters in Colorado?" To answer the question, some 500 seedlings were supplied by the U. S. Forest Service, Salinas, Calif.

These plants were shipped to 10 localities in the state representative of the various climate zones. The locations were: Fort Collins in north-central Colorado; Akron, representing the northern plains section: Fort Lewis, representing the southwestern section; Center in the San Luis Valley; Austin and Fruita in the Grand Valley; Rocky Ford, La Junta, and Lamar, representing the Arkansas Valley; and Trinidad in the south-central part of the state.

A brief description will be given of the various plantings, the soil types at the various locations, and a summary table of the growth and survival of the plants up until cold weather stopped growth in September.

The plants received at Fort Collins were planted on the Agronomy Farm on May 11 in rows 3 feet apart, 3 feet between the plants in the row. They were carefully watered for a few days after planting and were well established by June 26. Measurements were taken on the plants throughout the season. The final measurement was taken on September 26. No water was applied to the plants after they became established.

The soil type on which the plants were grown at Fort Collins is described as follows:

The soil is classified as Fort Collins loam[1] (Bureau Survey Series 1927). The surface layer is a grayish-brown friable loam to a depth of about 4 inches. Beneath this layer is about 6 inches of brown friable loam, weakly cloddy in structure. It is firmer in position than the layer above, but not compact. Underlying this layer is about 15 inches of light clay loam, cloddy, calcareous, and light grayish-brown in color. Beneath this is a layer of very light grayish-brown friable silt loam, 15 to 20 inches thick. This layer is calcareous but less so than the basal part of the one above. At about 4 feet the soil merges into the light-gray friable parent material of varied composition. Soils of this series are developed on stream terraces from calcareous alluvial deposits of moderately fine texture having no more than a scattering of gravel. Natural vegetation for the series: Mainly grama, buffalo and wheat grasses.

### U. S. Dry Land Field Station, Akron, Colorado

Mr. J. F. Brandon reports that the plants were planted on April 27 on the west orchard. They were watered until established. The first measurements were made on June 4. The final measurements were made in November. The soil

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[1]The soil classifications were furnished by Professor Dale S. Romine of the Agronomy Section.

at Akron is classified as Weld silt loam. It is a light brown loam underlaid at a depth of 12 to 15 inches by a calcareous layer. The subsoil is slightly heavier in texture than the surface soil.

Fort Lewis Substation, Hesperus, Colo.

Mr. Dwight Koonce reports as follows: Fifty guayule plants were planted May 1 on the Campbell ranch 16 miles north of Cortez, Colo., on Federal Highway 160, a short distance from the post office of Yellow Jacket. The planting was made on non-irrigated clay soil. The plants were cultivated once and were left free of weeds. Twenty-four plants survived the season. The data on the season's growth are presented in Table 1.

Experimental Substation, Austin, Colo.

Mr. F. M. Green reports that 74 plants were planted on April 28 of strains CA-1 Var. 406. The majority of the plants became well established. Mr. Green reported some injury from attacks by the striped flea beetle in June. The plants were sprayed on June 12 with arsenate of lead. Measurements on the season's growth were taken on August 8.

Another lot of plants furnished Mr. Green were planted on the farm of Guy McDaniels at Fruita. The plants were also attacked by flea beetles in June and were dusted with Pyrocide dust for control. The final measurements of the season were taken August 8. The plants were planted on April 30. Mr. Green reports considerable loss from root rot.

The soil description of the Austin farm follows: In the Western Colorado General Reconnaissance Survey (SCS Western Colorado Reconnaissance, 1939) the soil on the Austin Substation is mapped as "orchard clay loam." The Western Colorado Survey is a very broad reconnaissance, so the information on the small area may not be very reliable. The orchard series has developed on mesas of outwash materials derived almost wholly from the basic-igneous (basalt) formations capping the western end of Grand Mesa. The surface soils are light reddish brown, friable and calcareous. They have a crust-mulch development. The upper subsoil is a calcareous clay loam, light reddish brown to reddish brown in color. This layer is compact and has faint vertical cleavage. The lower subsoil beginning at about 12 inches is a grayish-brown, highly-calcareous clay. Some basalt gravel and cobble along with lime incrustations occur in this layer which is very compact, but under pressure breaks down into irregular clods and fine particles. Underlying the lower subsoil is an unassorted mixture of sandy material, waterworn basaltic gravel, cobble and angular fragments. This zone is very calcareous and moderately compact but not cemented. Shale underlies the soil at a depth ranging from 3 to 6 feet of the surface. The natural vegetation for the series is sagebrush, shad-scale, and some grasses.

Arkansas Valley Substation, Rocky Ford, Colo.

Mr. Herman Fauber, Superintendent, received 200 plants, 50 of which were planted on the Rocky Ford Station and lots of 50 were sent to La Junta, Lamar, and Trinidad. A good stand was obtained on the Rocky Ford Station. In August the average height of the plants was 9.05 inches with a width of 9.55 inches. The tallest plant was 13 inches and the largest crown was 13 inches. At this time the plants were shooting seed stalks. In December Mr. Fauber reported the average height as 17 inches and the diameter as 16 inches.

Table 1. Summary of results obtained from guayule plants grown in Colorado in 1942-43.

| | Fort Collins | Akron | (Ft. Lewis) Cortez | Center | Austin | Fruita | Rocky Ford | Lamar | Trinidad | La Junta |
|---|---|---|---|---|---|---|---|---|---|---|
| Date planted | May 11 | Apr. 27 | May 1 | Apr. 27 | Apr. 28 | Apr. 30 | Apr. 25 | | May | |
| Date measured | Sept. 26 | Nov. | Aug. 31 | Sept. | Aug. 8 | Aug. 8 | Dec. | Nov. | Nov. 6 | |
| Average growth for season-Ins. | 9.74±1.48 | 8.96±.59 | 8.23±1.69 | 6.5 | 9.95±1.21 | 9.03±1.78 | 17.00 | 10.0 | | |
| No. plants planted | 60 | 54 | 50 | 30 | 74 | 44 | 50 | 23 | 55 | |
| No. survived | 47 | 37 | 24 | 20 | 69 | 29 | 35 | 12 | 39 | |
| Pct. survival | 78.3 | 68.5 | 48.0 | 66.7 | 93.2 | 65.9 | 70.0 | 52.2 | 70.9 | |
| Sample analyzed | 6 | 6 | 10 | | 10 | 10 | 15 | | 12 | 0 |
| Survival - April 1943 | 0 | 0 | 0 | | | | 0 | 0 | | Plowed up |

The soil type of the Rocky Ford Substation is classified as follows: The soil is mapped as Rocky Ford loam (Bureau Survey Series 1926). The surface soil is a brown to reddish-brown mellow and friable fine-textured fine sandy loam or light loam to a depth of about 12 inches. Distributed through this layer is a small amount of medium and coarse sand. The next lower layer consists of light brown fine-textured loam extending to a depth of about 36 inches. This layer is heavier in texture than the soil above it or the deep subsoil below it. Light gray spots of lime accumulation are present. The deep subsoil of light silt loam is underlain by fine sand and stream gravel at a depth ranging from 6 to 10 or more feet. Natural vegetation for the series: buffalo and grama grasses predominate. The stand is rather thin compared to that in shortgrass regions of more effective precipitation.

Unfortunately, the test at La Junta was plowed up before any data could be calculated.

Lamar, Colo.

The plants were planted on the land of the Brown Nursery. After plants had been shipped for analysis, Mr. Droge of the Extension Service made the following report. "There were four plants which appeared more thrifty than the others. They measured about 16 inches in height and from 12 to 18 inches in diameter. Another plant measured 12 inches high and 8 inches across, and one small plant about 4 inches high and 3 inches across. No definite record was left of irrigation, but they were irrigated about 12 times during the season beginning the last week in May."

The soil where the guayule plants are planted is mapped as Manvel fine sandy loam (Bureau Survey Series 1926). The surface soil is a brown fine sandy loam to a depth of about 15 inches. This layer clods slightly under cultivation but breaks down rather easily. Underlying this is a slightly lighter brown and heavier fine sandy loam which continues to a depth of about 30 inches, where soil of the same color but of lighter texture is reached and extends to a depth of 6 feet or more.

On account of its high content of fine sand throughout the profile the soil is not as productive as the heavier types of this series. Natural vegetation for the series: shortgrasses, including grama and associated species, with some sage on the sandier types.

Twenty-three plants were planted, 12 of which survived the season. Six of these were shipped to the Colorado Agricultural Experiment Station for analysis in November.

San Luis Valley Substation, Center, Colo.: Alfred T. Kramer, Superintendent

Thirty plants of guayule were set out on April 27, 1942, in the northeast corner of the grass variety plots. Twenty plants survived on June 6. Mr. Kramer reports that temperatures were below freezing about 15 nights between April 27 and June 6. The average height of plants on June 6 was 2 inches. Ten plants were shipped to the Agricultural Experiment Station for chemical analysis when growth stopped in the fall. Nine plants were left to determine their ability to over-winter. The average height of the plants was June, 2 inches; July, 4½ inches; August, 6 inches; and September, 6½ inches.

The soil of the San Luis Valley Substation is classified as San Luis sandy loam (Bureau Survey Series 1903). The soil is a coarse, gravelly, reddish-brown sandy loam, varying in depth from 18 inches to 3 feet. Below this depth, the amount of sand and gravel increases until a mixture almost pure sand and gravel is reached.

Trinidad, Colo., McDonald Farm near Hoehne

The guayule plants are planted on a garden plot which has been given heavy applications of barnyard manure for a number of years and has been under irrigation. There were 55 plants planted on the McDonald place, of which 30 have survived. Twelve of these plants were shipped for chemical analysis on November 7. The soil on which the guayule plants were planted is classified as Apishapa loam. The surface layer is a dark brown friable loam to a depth of 18 inches. From 18 to 24 inches the soil is of the same general character as that of the surface 18 inches, but is somewhat lighter colored. This is underlain with a heavy olive-colored clay layer about 12 to 14 inches in thickness below which the soil is heavy and wet, and contains moderate to high concentrations of salt. The entire plot and surrounding land is poorly drained. The natural vegetation for the series is grama, western wheat and salt grasses and bush cacti.

The variation in growth of the plants at various locations is given in Table 1. Where sufficient data is available to determine variability, no significant difference was noted in the annual growth. The plants at the San Luis Valley averaged the shortest, those at Rocky Ford the longest. The plants at Fort Collins, Akron, Austin, and Fruita made about the same amount of growth.

Russian Dandelion (Taraxacum kok-saghyz)

Four plantings of Russian dandelion were made in Colorado in 1942, one at each of the following stations: Agronomy Farm, Fort Collins; Rocky Ford Substation; U. S. Dry Land Field Station, Akron, Colo.; and the Fort Lewis Substation at Hesperus, Colo. Two lots of seed, one vernalized and one untreated, were received late in May. Seed from both lots were planted at Fort Collins on June 8. The land was cultivated prior to seeding and irrigated. As soon as it was suitable to work, it was levelled and planted. The weather was damp and cool after planting and good germination should have been obtained; however, very poor emergence was obtained. The plants were irrigated on July 12 and 13 and were weeded July 17, 18, and 20. At this time all plants were marked with stakes. Considerable insect damage was noted on many of the young plants. On November 6 the bulk of the plots was harvested and forwarded to Dr. C. E. Steinbauer, U.S.D.A. Rubber Plant Field Laboratory, University Farm, St. Paul, Minn., for analysis. Several plants were also analyzed by the Chemistry Section. The remaining plants were left in the ground and survived the winter. Samples were sent in to the Chemistry Section of Colorado Agricultural Experiment Station for analysis in April.

Additional plantings were made in September of 1942. Several methods of treating the plots, including a straw mulch, were used. A severe wind storm in February damaged the stands and no plants were showing on March 25. Additional plantings will be made in April.

Poor stands were obtained at Rocky Ford, Akron, and Fort Lewis. Before yield tests can be made a suitable method of obtaining a stand will have to be developed.

Hemp dogbane (Apocynum cannabinum)

Seed of this species were planted on the Agronomy Farm in May. No plants emerged.

Several other native plants were collected by members of the Rubber Committee and analyzed by the Chemistry Section. A report of these analyses has already been presented. Information on the plants collected can be obtained from the report of the Chemistry Section, Colorado Agricultural Experiment Station.

State of Growth of Prickly Lettuce,
Collected for Rubber Analysis, 1942

The stand of Lactuca scariola from which the samples were taken was growing on land that had been in corn in 1941. No irrigation was given in 1942. This land was probably not irrigated in 1941.

Samples were taken from two locations (A and B) in the field. Tops only (cut with a sickle at 2" ht.) and tops and roots (pulled) samples were taken from each location, as indicated by the letters A and B. Samples were taken on three dates. Growth was as follows:

July 15 -- early bud stage; racemes had not formed on this date.

Aug. 5 -- early flower; about one-third of the lower leaves were dead. A rather heavy infestation of mildew was present on the green leaves.

Sept. 30 --plants mature, heavily laden with seed; all leaves and stems were apparently dead.

Agronomic data on prickly lettuce (Lactuca scariola)
Collected for rubber analysis - 1942

| | Height inches | No. plants per square meter | Green weight-Grams per square meter quadrat* | Green weight-Tons per acre |
|---|---|---|---|---|
| Harvested July 15 | | | | |
| Tops only: | | | | |
| Quadrat A | 58 | 28 | 4412 | 19.68 |
| Quadrat B | 54 | 38 | 3811 | 17.00 |
| Average | 56 | 33 | 4111 | 18.34 |
| Tops and roots: | | | | |
| Quadrat A | 61 | 55 | 5700 | 25.43 |
| Quadrat B | 60 | 32 | 4789 | 21.36 |
| Average | 60 | 43 | 5244 | 23.39 |
| Harvested Aug. 5 | | | | |
| Tops only: | | | | |
| Quadrat A | 90 | 43 | 4526 | 20.19 |
| Quadrat B | 84 | 41 | 4530 | 20.21 |
| Average | 87 | 42 | 4528 | 20.20 |
| Tops and roots: | | | | |
| Quadrat A | 90 | 33 | 5579 | 24.89 |
| Quadrat B | 83 | 73 | 4381 | 19.54 |
| Average | 86 | 53 | 4980 | 22.21 |
| Harvested Sept. 30 | | | | |
| Tops and roots: | | | | |

Fig. 1. A diseased plant at Fort Collins.

Fig. 2. Left, plant at Fort Lewis, Colo., July 30. Right, a plant at the Austin Sub-station in August.

Fig. 3. A general view of the planting on the Austin Substation, August 1942.

Fig. 4. Exhibit of rubber-bearing plants of Colorado, Colorado State Fair, 1942. Prepared by the Botany Section, Agricultural Experiment Station.

# THE "RUBBER" CONTENT OF SOME COLORADO-GROWN PLANTS

Preliminary Report - December 1942

J. W.Tobiska and C. E. Vail, Chemistry Section

With the current shortage of rubber in the United States under present war conditions, a lively interest has been aroused in the possible sources of this substance within our own borders. This search for sources has taken two principal trends which in order of their immediate importance appear to be, first, the increased production of synthetic rubbers; and second, the survey of potential sources of natural rubber from plants growing within our own neighboring countries. This report treats of studies made within the State of Colorado.

At the close of World War I some investigations were being carried on looking toward the possible production of rubber from natural plant sources. Perhaps the only one of these which survived the first war and has been continued by private concerns up to the present is the investigation of the shrub guayule, or Mexican rubber plant.

A revival of interest in plant sources of rubber has been manifested during the present emergency, and many of the experiment stations at land-grant colleges have undertaken surveys of the possibilities of the native plants in their respective states.

Such a preliminary survey of native plants and some introduced species has been undertaken in Colorado. During the past growing season, a number of species were collected by several sections of the Experiment Station and at least two introduced species, guayule and kok saghyz (Russian dandelion), have been grown for one season in several locations within the State.

The following tabulations represent the findings to date on the plants investigated.

Table I-A.--Lactuca scariola (tall wild lettuce)
(Acetone-benzene extraction method on air-dried plant material)

This tall wild lettuce was collected by D. W. Robertson of the Agronomy section on vacant lots near the college farm. Three sets of samples were taken as the table shows (on July 15, Aug. 5, and Sept. 30) and in duplicate labelled quadrat A and quadrat B. The material was quickly dried and the stems put through steel rollers and finally through a Wiley mill. The ground material, 20-30 mesh, was subsequently extracted with acetone for 12 hours, followed by extraction with benzene for 12 hours (Pickel extractor used). From the average total yield of gum per sample it appears that about August 5 is the correct time to harvest in order to obtain maximum yield per acre.

Table I-B.--Guayule, or Mexican rubber plant.
(Comparison of acetone-benzene and modified Edison methods)

The guayule plants represented in these analyses were obtained by D. W. Robertson of the Agronomy section through U.S.D.A., presumably as 1-year-old transplants. Fifty plants were planted early in the spring of 1942 in each of 10 locations in Colorado. Ten plants from each location were harvested in the late fall

as shown in the table and sent to the Chemistry section for analysis of rubber content. It appears that the analyses represent plants about 18 months old. The remaining 40 plants at each location were left in the ground to obtain information on whether or not they will live through our Colorado winter.

When the samples reached the laboratory they were separated into roots, stems, and leaves, and these parts were analyzed separately. The dried stems and roots were rolled thin between steel rollers and subsequently ground to a 20-30 mesh fineness by means of a Wiley mill.

These samples were analyzed by the acetone-benzene method and again by the modified Edison method for the purpose of comparisons, which are shown in the table.

Based on 10 plants it may be seen that both the growth made in one season and the total rubber content from the nine locations tested varied rather widely and in a very irregular manner. This may be taken as an indication that both cultural methods and climate affect the rubber content of the plants. On the basis of one season's results the locations may be aligned in the following order, according to the amount of rubber produced from guayule:

1. Trinidad
2. Rocky Ford
3. Austin
4. Lamar
5. Fruita
6. Akron
7. Cortez
8. Fort Collins
9. San Luis Valley(Monte Vista)

Table I-C.--Miscellaneous Native Plants. (Acetone-benzene extraction of air-dry material)

This table represents miscellaneous plants, and with the exception of kok saghyz these were plants native to Colorado. They were collected by the Chemistry section and Range Management section of the Experiment Station and by the Rocky Mountain Forest and Range Experiment Station.

The Russian dandelion (kok saghyz) was obtained from U.S.D.A. and grown from seed by D. W. Robertson on the Agronomy farm.

Most of these samples were tested only by the acetone-benzene method, but for purposes of comparison a few were also tested by the Edison bromination method.

Table I-A.--*Lactuca scariola* (Tall wild lettuce) (Air-dried material). Acetone-benzene method.

| Sample No. | Date collected | Plant part | Quad. | Total weight | % gum | Average grams gum in total sample |
|---|---|---|---|---|---|---|
| | July 15, 1942 | Roots | A | 152g | -- | |
| 1 | " | Stem | " | 710 | .16 - .20 | |
| 2 | " | Leaves | " | 282 | .45 - .69 | |
| 5 | " | Stems | " | 500 | .24 - .41 | 3.492 |
| 6 | " | Leaves | " | 265 | .95 - .71 | |
| | Aug. 5, 1942 | Roots | " | 142 | -- | |
| 3 | " | Stems | " | 965 | .24 - .22 | |
| 4 | " | Leaves | " | 407 | .98 - .74 | |
| 7 | " | Stems | " | 885 | .18 - .22 | 5.297 |
| 8 | " | Leaves | " | 357 | - - .87 | |
| | Sept. 30, 1942 | Roots | " | 231 | -- | |
| 17 | " | Stems | " | 602 | .38 | |
| 18 | " | Leaves | " | 340 | .76 | 4.871 |
| | July 15, 1942 | Roots | B | 112 | -- | |
| 9 | " | Stems | " | 545 | .37 | |
| 10 | " | Leaves | " | 314 | .62 | |
| 13 | " | Stems | " | 382 | .49 | 4.011 |
| 14 | " | Leaves | " | 238 | .92 | |
| | Aug. 5, 1942 | Roots | " | 138 | -- | |
| 11 | " | Stems | " | 775 | .38 | |
| 12 | " | Leaves | " | 307 | .77 | |
| 15 | " | Stems | " | 855 | .50 | 5.488 |
| 16 | " | Leaves | " | 387 | .36 | |
| | Sept. 30, 1942 | Roots | " | 429 | -- | |
| 17 | " | Stems | " | 827 | .38 | |
| 18 | " | Leaves | " | 281 | .76 | 5.277 |

Table I-B.--Guayule, or Mexican Rubber Plant

Comparison of Acetone-benzene (AB) and Modified Edison Bromination (Br) Methods on Air-dried Material. (Total Data on 10 plants.)

| Sample No. | Location | Date | Plant part | Tot.wt. g. | Tot. dry mat. | % Gum AB | % Gum Br | Total gum (Br) |
|---|---|---|---|---|---|---|---|---|
| 57 | Fort Collins | 9/29/42 | root | 51. | | .49 | .457 | |
| 58 | " | " | stems | 93. | 365.g | .58 | .238 | |
| 59 | " | " | leaves | 221. | | 1.46 | .107 | .690g. |
| 60 | San Luis Valley | 9/22/42 | roots | 22. | | .67 | .558 | |
| 61 | Monte Vista | " | stems | 49. | 145g. | .95 | .607 | |
| 62 | " | " | leaves | 74. | | .35 | .123 | .410g. |
| 63 | Cortez | 9/23/42 | roots | 23.5 | | .93 | .628 | |
| 64 | " | " | stems | 64.0 | 190.5g. | .67 | .285 | |
| 65 | " | " | leaves | 103.0 | | .33 | .158 | 1.821g. |
| 66 | Akron | 10/5/42 | roots | 53. | | .47 | .308 | |
| 67 | " | " | stems | 141. | 509.0g. | .22 | 1.387 | |
| 68 | " | " | leaves | 315. | | 1.88 | .084 | 2.383g. |
| 69 | Fruita | 10/12/42 | roots | 74. | | .71 | .559 | |
| 70 | " | " | stems | 322. | 763.0g. | 1.17 | .836 | |
| 71 | " | " | leaves | 367. | | 1.59 | .197 | 3.829g. |
| 72 | Austin | 10/17/42 | roots | 84. | | 1.03 | 1.337 | |
| 73 | " | " | stems | 278. | 634.0g. | 2.59 | 1.595 | |
| 74 | " | " | leaves | 272. | | .97 | .321 | 6.430g. |
| 75 | Rocky Ford | 10/28/42 | roots | 266. | | .75 | .670 | |
| 76 | " | " | stems | 794. | 2038.0g | 1.91 | 1.325 | 14.434g. |
| 77 | " | " | leaves | 978. | | 2.42* | .218 | |
| 93 | Trinidad | 11/9/42 | roots | 52.5 | | 1.46 | 1.647 | |
| 94 | " | " | stems | 99.2 | 266.7g. | 1.18 | 1.269 | 21.498g. |
| 95 | " | " | leaves | 115.0 | | .35 | .229 | |
| 96 | Lamer | 11/16/42 | roots | 90. | | .66 | .581 | |
| 97 | " | " | stems | 344. | 702.0g. | 1.30 | 1.180 | |
| 98 | " | " | leaves | 268 | | .59 | .141 | 4.960g. |

*When extracted with 80% acetone instead of 100% acetone the gum content dropped to .33%

Table I-C.--Miscellaneous Native Plants
Acetone-benzene extraction of air-dry material

| Sample No. | Name | Date | Plant part | % gum A-B | Location | Common name |
|---|---|---|---|---|---|---|
| 19 | Latuca pulchella | 9/14/42 | stems | 1.05 | Fort Collins Airport | Blue lettuce |
| 20 | " | " | leaves | 1.46 | " " " | " " |
| 21 | Asclepias arenaria | 8/21/42 | stems | .20 | " ", South Shields St. | Showy milkweed (good fiber) |
| 22 | " | " | leaves | .90 | " " " " " | Showy milkweed |
| 23 | " | 9/42 | one plant | .76 | Near Deer Trail (by Forest Sta.) | " " |
| 24 | " | 9/1/42 | stems | .25 | College Pasture, Fort Collins | " " |
| 25 | " | " | leaves | .91 | " " " " | " " |
| 26 | Apocynum androsemaefolium | 9/11/42 | stems | .26 | North of Fort Collins | Dogbane (good fiber) |
| 27 | " | " | leaves | 1.24 | " " " " | " |
| 28 | " | 9/20/42 | whole | .82 | East of Delta (by Forest. Sta.) | " |
| 29 | " | 8/16/42 | whole | .54 | Rist Canyon, Fort Collins (by C. H. Wasser) | " |
| 30 | " | " | whole | .54 | " " " " " | " |
| 31 | Chrysothamnus nauseosus | 9/23/42 | young stems | .19 | San Juan region (by Forest. Sta.) | Rabbitbrush |
| 32 | " | " | old stems | .29 | " " " " " | " |
| 33 | " | 8/12/42 | young stems | .14 | Great Divide, Moffat Co.(by E.W.Nelson) | " |
| 34 | " | " | old stems | .49 | " " " " " | " |
| 35 | " | 9/23/42 | young stems | .39 | By Forest. Sta. | " |
| 36 | " | " | old stems | .38 | " " " | " |
| 37 | " | 8/1/42 | young stems | .48 | Aremmling, Colorado | " |
| 38 | " | " | old stems | .49 | " " | " |
| 39 | " | 8/12/42 | young stems | .38 | Craig, Colorado (by E.W.Nelson) | " |
| 40 | " | " | old stems | .49 | " " " " | " |
| 41 | Euphorbia | 8/22/42 | stems | .15 | Cheyenne Wells, Colo.(by C. H. Wasser) | Snow on the mountain |
| 42 | " | " | stems | .47 | " " " " " | " " " " |
| 43 | Solidago serosotum | 9/11/42 | stems | .41 | North of Fort Collins, Colo. | Goldenrod |
| 44 | " " | " | leaves | .66 | " " " " " | " |
| 45 | " " | " | fruits | .32 | " " " " " | " |

Table I-C. (Continued)--Miscellaneous native plants
Acetone-benzene extraction of air-dry material

| Sample no. | Name | Date | Plant part | % gum | Location | Common name |
|---|---|---|---|---|---|---|
| 46 | Green Gentian | 8/1/42 | stems and leaves | .37 | Kremmling, Colo. | |
| 47 | Senecio serra | 9/42 | stems and leaves | .23 | Vail Pass (by Forest. Sta.) | Ragwort or butterweed |
| 48 | Oxytenia acerosa | " | stems and leaves | .27 | Palisade, Colo.(by Forest. Sta.) | Sneezeweed |
| 49 | Veratrum viride | 8/1/42 | leaf sheathes | .16 | Kremmling, Colo. | Skunk cabbage |
| 50 | " " | " | leaves | .39 | " " | " " |
| 51 | Pingue | 3/18/42 | roots | 4.55-5.93 | Salida, Colo.(by Schmidt) | Colorado rubber plant |
| 52 | " | " | rhizomes | .81 | " " " | " " " |
| 53 | " | 8/10/42 | roots and rhizomes | 2.15 | South Park, Colo. A.(Forest Sta.) | " " " |
| 54 | " | " | young stems | .29 | " " " A. " | " " " |
| 55 | " | " | roots and rhizomes | 1.12 | " " " B. " | " " " |
| 56 | " | " | young stems | .34 | " " " B. " | " " " |
| 78 | " | 3/8/42 | linters | --- | Salida, Colo.(Schmidt) Ash 14.39% Crude fiber 32.62 | " " |
| 79 | " | " | medium waste | .78 | " " Sample #51 | " " |
| 80 | " | " | fine waste | .35 | " " | " " |
| 81 | " | " | concentrates | 2.85 | " " | " " |
| 84 | Kok saghyz | 11/6/42 | roots | 2.04 | Fort Collins, Colo.(Agron.Sec.) | Russian dandelion |
| 85 | " " | " | leaves | 1.02 | " " " " " | " " |
| 86 | Poinsettia | 11/5/42 | stems and leaves | .21 | Fort Collins (greenhouse) young plants | |
| 87 | Taraxacum leontodon | 11/7/42 | roots | .20 | Fort Collins, Colo.(behind grandstand-J.W.T.) | Common dandelion |
| 88 | " | " | leaves | .41 | " " " " | " " |
| 89 | " | 11/8/42 | roots | .16 | " " " (by C. E. Vail) | " " |
| 90 | " | " | leaves | .37 | " " " (By C.E.Vail) | " " |
| 91 | " | 11/9/42 | roots | .14 | " " "(By E.Douglass) | " " |
| 92 | " | " | roots | .39 | " " " | " " |
| 99 | Medicago L. (Lucerne) | | roots | .15 | Fort Collins, Colo. College Farm old roots (alfalfa) | |

Table I-D.--Miscellaneous plants
Comparison of benzene-acetone (AB) method with modified edison bromination (Br) method

| Sample No. | Date collected | Plant part | % elastomer | | Name | Common name |
|---|---|---|---|---|---|---|
| | | | AB | Br | | |
| 4 | 8/5/42 | leaves | .98-.74 | .172 | Lactuca scariola | Tall wild lettuce |
| 17 | 9/30/42 | stems | .38 | .006 | " " | " " " |
| 18 | " | leaves | .76 | .054 | " " | " " " |
| 19 | 9/14/42 | stems | 1.05 | .368 | Lactuca pulchella | Blue lettuce |
| 20 | " | leaves | 1.46 | .365 | " " | " " |
| 21 | 8/21/42 | stems | .20 | .073 | Asclepias arenaria | Showy milkweed |
| 22 | " | leaves | .90 | .963 | " " | " " |
| 26 | 9/11/42 | stems | .26 | .063 | Apocynum androsemaefolium | Dogbane |
| 27 | " | leaves | 1.24 | 1.076 | " | " |
| 37 | 8/1/42 | young stems | .48 | .690 | Chrysothamnus nauseosus | Rabbit brush |
| 38 | " | old stems | .49 | .165 | " " | " " |
| 81 | 3/8/42 | roots | 2.85 | 1.957 | Pingue (Salida, Colo.) | Colorado rubber plant |
| 84 | 11/6/42 | roots | 2.04 | 4.031 | Kok saghyz | Russian dandelion |
| 85 | " | leaves | 1.02 | 1.083 | " " (1-yr.old plants) | " " |
| 87 | 11/7/42 | roots | .20 | .264 | Taraxacum leontodon (Rydberg) | Common dandelion |
| 88 | " | leaves | .41 | .233 | " " | " " |

## General Discussion

From these preliminary investigations it would appear that very many plants in the course of their lifetimes do elaborate some small amount of a rubber-like complex. In addition they also appear to elaborate gummy substances which do not have the properties of rubber but are either true resins or substances of a rather carbohydrate character (true gums). The plants tested were either perennial woody shrubs or short-lived perennial herbs.

It would appear on the basis of present meager information that these plants may be divided into at least two general classes, namely, (1) the lactiferous (milk bearing) plants, such as the dandelion, wild lettuce, milkweeds, and dogbane, and (2) shrubby, woody plants which carry clear, gummy substances such as guayule, pingue, and rabbitbrush.

It is possible that further investigation would reveal the necessity of treating each of these classes of plants by different processes in order to obtain the best yields of the desirable rubber-like substances. Present indications lean toward the conclusion that the latex-bearing plants might best be treated in the fresh green state, while the woody shrubs may be dried, ground, and then extracted by suitable solvents which will give the highest yield of good-quality gum. Also, the lactifers appear to have more of the elastomer in the leaves rather than in the stems and roots.

On the basis of the few tests made, partial acid hydrolysis (1% HCl or $H_2SO_4$), and boiling or steaming to disintegrate woody fibers, does not appear to vitiate the amount of gum subsequently obtained, but alkali (NaCH) hydrolysis does appear to diminish the content of elastomer-tensomer gums.

## Methods

The first consideration deals with preparation of the sample for analysis. The present report does not include sufficient work with the latex plants to determine whether or not they could advantageously be treated in the undried condition. It was found that dried material could be prepared in a satisfactory manner by indoor drying, rolling the dried stems and roots between steel rollers, and subsequently running them through a Wiley mill to a fineness of 20-30 mesh. This appeared to be fine enough to permit penetration of the solvents and yet not so fine as to produce compaction in the extraction capsule.

Two principal methods of chemical extraction of the elastomer-tensomers were used in obtaining the data here presented.

### Method I.

The most common method, designated in its several modifications as the Hall-Goodspeed method, the Spence-Caldwell method, etc., depends upon the previous extraction of the dried materials with acetone and other solvents to eliminate the chlorophyll and like pigments and subsequent extraction of the elastomer-tensomers with benzene.

With this method it was found by the authors of this report that even prolonged extraction with pure acetone (12 hours) does not extract the chlorophyll bodies with any degree of completeness. Hence all early data so obtained are likely to be grossly inaccurate, depending in degree upon the amount of pigments remaining in the final gums. Thus, dried green foliage and green young stems of plants which appear to have larger quantities of gum than the older stems and roots must be discounted.

It was found by some preliminary tests that the old method of extraction of chlorophyll used by Willstätter in Germany gives much more complete extraction. He used an aqueous solution of acetone (80% acetone - 20% water). It was also found that in subsequent rubber extractions some materials extracted better with benzene while others gave higher yields with carbon tetrachloride.

It appears that complete extraction of elastomers requires a much longer time than the 3 hours specified in some methods, regardless of solvent used. The Bailey-Walker and the Pickel apparati are designed for dropwise extraction. After some experience with these extractors, the authors believe that the old Soxhlet apparatus is much better adapted to this type of work where complete extraction of larger samples is desirable. This is because the entire contents of the paper thimble are bathed in the solvent before being siphoned off, thus giving better opportunity for diffusion of the gums.

If it be desired to produce a sample of the elastomer for exhibit or further study of qualities, then it is probable that the following will prove satisfactory: A 12- to 16-hour extraction with 80% acetone, followed after drying by extraction of the gum with either benzene or carbon tetrachloride, and evaporation of the final solution. The latter extraction should also be of 12- to 16-hour duration and preferably in a Soxhlet type (siphon) extractor.

Method 2

On the other hand, if it be desired simply to estimate the quantity of unsaturated hydrocarbons (i.e., the dienes which are taken to constitute the basis of the elastomer complex), then the modified Edison bromination method would perhaps be the more satisfactory. This method depends upon the solubility of chlorophyll pigments as well as the elastomer gums in carbon tetrachloride.* After solution is effected the pigments are held in solution with absolute ethyl alcohol while the unsaturates (dienes) are precipitated by bromine in solution in carbon tetrachloride. The precipitate may be washed and centrifuged several times (using absolute alcohol as wash) then dried and weighed. The factor for conversion to elastomer in this latter precipitate is taken by the authors of the method to be 28.5%.

Tentative Conclusions

1. Very small amounts of elastomer were found in all herbs and shrubs tested.
2. Among the native plants of Colorado, 11-year-old pingue roots were found to contain the highest percentage of good quality elastomer, i.e., 5.93% on air-dry roots (acetone-benzene method). Other plants were found to carry as follows (modified Edison method):

| | | | |
|---|---|---|---|
| Dogbane, leaves | 1.07% | Lactuca scariola, leaves | .054% |
| Milkweed, leaves | .96% | Rabbitbrush, stems | .69% |
| Blue wild lettuce, stems and leaves | .37% | Common dandelion, roots | .26% |
| | | Pingue, younger roots | 1.96% |

*The original Edison method was benzene

3. Among the introduced species of plants (modified Edison method)

| | | | | | |
|---|---|---|---|---|---|
| Kok saghyz (1-year-old roots) (Fort Collins) | | yielded | 4.03% | good | quality gum |
| Guayule (18 months old) (Trinidad) | roots | yielded | 1.65% | " | " " |
| | stems | " | 1.27% | " | " " |
| | leaves | " | .23% | " | " " |

4. A solution (80% acetone, 20% water) extracted chlorophyll and other pigments much more effectively than did pure acetone.

5. Effective extraction of elastomers with either benzene or carbon tetrachloride required much longer than the 3 hours stipulated in some of the published methods. Twelve or 16 hours appeared to be more nearly the correct time.

6. A siphon type (Soxhlet) extractor for air-dry samples of 2 to 5 grams would appear to be more satisfactory for this type of work than the dropwise extractors (Bailey-Walker or Pickel).

Note: Abstract of Spence-Caldwell Method, I. & E. C., Anal. Ed., 5:375
5-gram sample, in Coors porcelain extraction thimble; layer of wool below and above sample. Boil in 1% $H_2SO_4$ for 3 hours; autoclave 3 hours at 30#; extract with water by percolation for 3 hours; extract with acetone 12 hours; dry in vacuum over 1/2 hour; extract with benzene 16 hours; evaporate, dry, weigh. 5cc 0.1% soln. dimethyl-p-phenylene-diamine in benzene added before evaporation (as a stablizer).