UNIVERSITY OF ARIZONA

Arizona Agricultural Experiment Station.

BULLETIN NO. 21.

CANAIGRE.

BY

ROBERT H. FORBES,

CHEMIST.

Tucson, Arizona, July, 1896.

Arizona Agricultural Experiment Station.

STATION STAFF.

HOWARD BILLMAN, A. M.........President
WM. STOWE DEVOL, B. Agr., Director.........Agriculturist and Horticulturist
EDWARD M. BOGGS.........Irrigation Engineer and Meteorologist
JAMES W. TOUMEY, B. S.........Botanist and Entomologist
ROBERT H. FORBES, B. S.........Chemist

MARK WALKER, JR.,.........Ass't in Chemical Laboratory } Station
G. M. GILLETT.........Ass't Meteorologist } No. 1,
LEE LACHANCE.........Stenographer } Tucson.
N. H. CLAFLIN, M. D., Foreman.........Station No. 2, Phoenix

The Bulletins of the Station are sent gratis to all residents of Arizona applying for them.

The Experiment Station respectfully solicits suggestions relating to the important work it is attempting to accomplish in the development of the agricultural resources of the Territory.

Questions upon subjects within the scope of the Station work will be cheerfully answered whenever possible.

Address all communications to

DIRECTOR EXPERIMENT STATION,

Tucson, Arizona.

CANAIGRE.

By Robert H. Forbes.

SYNOPSIS:

INTRODUCTORY.

The object of this bulletin is to make a careful and fairly complete statement of facts regarding canaigre, and on this basis in some measure to advance practical suggestions. This involves not only the setting forth of new observations, but also a restatement and revision of some material that, in substance, has appeared before. Owing, however, to the novelty of this subject to the general public such repetition is deemed well worth while. From a commercial standpoint our present knowledge of canaigre is quite satisfactory excepting as to the methods and results of agriculture for the plant, and it is thought that comprehensive information at the present time will be valuable to those who are interested in demonstrating this remaining point and in forming a judgment of the future of the industry.

THE CANAIGRE PLANT.

Habitat, Name, Description.—Canaigre (Rumex hymenosepalus) is, roughly speaking, native to that region known by some botanists as the arid Lower Sonoran life zone. This is an irregular area which proceeds northward from the highlands of the interior of Mexico, covers the northern and northwestern portions of that country, and in the United States extends from Oklahoma and Central Texas westward across Southern New Mexico and Arizona, includes the southwestern corner of Utah, the southern third of Nevada, and all of Southern California except the mountains, then finally sends its arms up the San Joaquin and Sacramento Valleys, and down the peninsula of Lower California. This vast region is in the main remarkable for its exceedingly dry climate, its hot summers, and its long, mild winter season. Consequently it possesses many peculiar forms of animal and vegetable life, of which canaigre is one.

"Canaigre" is the American corruption of the Spanish "caña agria" (sour cane) by which the plant is chiefly known in Mexico. It is also called "yerba colorado" (red root) by the Mexicans. In other localities canaigre seems to have various popular names such as "tanner's dock," "red dock," and "wild rhubarb."

Popularly, canaigre is described as resembling many of the common docks. The broad, smooth, light green, usually wavy margined leaves, spreading at the surface of the ground, often attain a length of twenty inches including the strong succulent stalks which support them, and which in shape somewhat resemble the stems of common pieplant. The stout, somewhat leafy, and compoundly branching blossom stalk of the mature plant sometimes attains a height of more than three feet, usually, however, much less than that. The seeds, often more than a thousand in number, are supported in small clusters on slender pedicels along the branches of the flower panicles. Each seed is winged with three heart-shaped leafy bracts about half an inch long. These bracts are usually pinkish or sometimes *strongly red, while the lower parts of leaf and blossom stalks* and the *midribs and margins of leaves are commonly tinged* with the same color. The seed proper is dark brown when ripe, about one fourth of an inch long, three cornered, and resembles small buckwheat is general appearance.

Canaigre is chiefly remarkable for its tuberous roots, varying under different conditions of growth from almost globular to long and slender forms. Outside of the tubers the root system is not extensive being distinctly smaller than that of beets or potatoes. (See Fig. 4). In weight the roots range from a fraction of an ounce to two pounds. Externally, the young roots are light in color, changing to brown, reddish brown or almost black with age. They live several years, usually five or more, but show very little new growth after about the third season. The root increases after the manner of all exogenous stems by adding a layer of new tissue to the heart from without and to the bark from within. At the end of the growing season this white zone of new growth may always be found in living roots between bark and heart, and, since the tissues tend to deepen in color from year to year, the older portions of the root, consisting of the inner heart and the outside layers of bark usually possess much more coloring matter. Oftentimes the gradations of color in successive rings of growth are so sharply marked that the age of a root is roughly shown by its cross section.

The brittle, heavy bark, often a quarter of an inch in thickness, is externally quite smooth in young roots, with occasional scars marking the points of attachment of small rootlets during the period of growth. The old roots are rougher, often shaggy and deeply cracked as the result of rapid growth. The growing buds are at the crown of the root and are sometimes also borne on the fleshy base of the stems, which occasionally do not die but persist, seemingly in order to bring the buds nearer to the surface when the roots have been too deeply buried. In young roots the buds are conspicuous and prompt to grow but small and sluggish in old ones.

The roots, usually erect in position, appear normally at less than one foot below the surface. The root clusters, containing tubers of every size and age, vary much in arrangement. Roughly speaking, the new roots surround the mother tubers making a cluster in which the old growth is centrally placed. Often times the new roots happen to form on one side of the mother tuber and, continuing in that direction make a chain of roots connected at their crowns and in which the old growth is at one end, the new at the other. Increasing in this manner, the number of living roots in a single colony is sometimes very large. A thrifty hill dug in a sandy wash near Tucson recently yielded 91 roots weighing about 8 pounds, while a cultivated hill three years old from Phoenix gave 87 roots weighing 17.5 pounds.

As they grow older, the roots become more and more dormant, showing less tendency to throw up shoots of their own, but maintaining a feeble vitality through their connection with younger roots. In Nature the old roots seem to serve as a safeguard against extermination, being less easily affected by adverse conditions. They also seem to be concerned in the work of seed production since it appears, other things equal, that good seed stalks are associated with strong old roots. Seedling roots do not produce seed during their first year of growth.

The seeds, especially in arid situations, are largely infertile. In this section wild seedlings have not been observed though said to be common in certain moist localities of New Mexico and California. In one trial of mixed wild and cultivated seed, two years old, sown in drills one half inch deep, nine per cent came up. In Nature canaigre is spread by occasional seed germination and by accidental scattering of roots, but is maintained in place by its peculiar root system.*

Conditions of Growth.—The best conditions for the growth

*For a more detailed botanical description see the Arizona Experiment Station Bulletin No. 7, pages 10-22, by Professor J. W. Toumey.

of canaigre are a cool but not freezing climate, a moderate amount of moisture, a sandy, fertile soil, and probably, also, a sunny and arid atmosphere. These conditions are nowhere combined more perfectly or for a longer period of the year than during the six or seven cooler months in the arid Southwest.

The relation of heat and moisture to the growth of canaigre is shown by the accompanying table giving temperatures (in degress F.) and rainfall for one year at Tucson, Arizona together with the condition of the growing plant at the same time.

TABLE I.

Relation of Heat and Rainfall to Growth of Canaigre.

1895-96.	Temperature.			Inches of Rain.	Condition of Canaigre.
	Max	Min	Mean		
May	101.5	47.0	74.7	.09	Tops of plants died back by May 25th.
June........	107.9	45.4	81.1	.03	Roots inert.
July	106.5	63.0	86.1	.11	Roots inert
August......	106.0	61.3	82.8	4.48	Rains in August caused roots to sprout, but they did not continue to grow.
September ...	107.0	50.5	80.8	.75	Sprouted roots did not continue to grow.
October.....	92.6	38.5	68.8	.68	Plants began to grow vigorously under influence of cool weather.
November ...	83.1	27.1	53.5	4.30	Plants grew rapidly.
December ...	85.4	13.9	46.9	.08	Plants grew rapidly and new roots began to form.
January.....	89.4	23.3	56.6	.53	New roots increased rapidly.
February	83.3	25.7	56.6	.08	New roots increased rapidly, blossom stalks appeared.
March	94.1	27.0	61.2	.27	New roots increased, plants blossomed and set seed.
April	93.0	31.0	63.7	.12	Leaves began to die at end of month. Some second growth was observed.

This table shows that a mean temperature of about 70 degrees or less is required for the growth of canaigre. Above this, even though there be abundant rain, as was the case in August, the roots will not do more than sprout feebly, and various attempts to make them grow in warm weather have failed. This seems to limit canaigre to the Southwest, for nowhere else, excepting possibly in some Southern States is there so long a period of mild weather. It has been grown experimentally in Florida with some success but in the Northern States the interval between the severe cold of winter and the extreme heat of summer is too short to allow of much root development. The sprouting of the roots in August under the influence of rain suggests that in the culture of canaigre one or two summer irrigations would prepare the plant to grow more promptly on the advent of cool weather.

The growing plant will stand a good deal of cold. When frosted the leaves lie prostrate upon the ground, but immediately regain position when thawed out by the sun. The root also will endure freezing. It has been left in the ground all winter sixty miles north of New York City "subjected to a temperature as low as 15 degrees below zero, without injury." At Lincoln, Nebraska, the roots stood a very severe winter "without any damage whatever." At Peoria, Illinois, plantings made in 1892 were still alive in 1895, and similar results are noted at Washington, D. C., and Garden City, Kansas. The new root development, however, is stated in a number of cases to be insignificant under such conditions.*

As to locality, canaigre is found most commonly in sandy washes where water is more abundant. With irrigation it will make a good growth in any fertile, tillable ground, but the influence of soil conditions on actual production has been little studied. It seems to stand considerable alkali and is even reported in the salt grass meadows of Tia Juana Valley near San Diego, California.

*Through correspondence.

Insect Enemies and Diseases.—Canaigre is not without its insect enemies. The canaigre beetle (Gastroides cyanea, Welsh. var. caesia, Rog.) and its larva feed upon canaigre leaves. Its eggs look like those of the potato beetle. Its larva, with black head and dark body, is about one quarter of an inch long and the greenish or very dark mature insect is only one twelfth of an inch in length. The ravages of this insect are sometimes very considerable. This year (1896) the wild growth was badly riddled in some localities near Tucson. The amount of injury to cultivated crops which this insect may do, can not be stated at present. The root is eaten by at least two grubs, as yet unnamed. One of them is the inch long larva of a Lamellicorn beetle, the other resembles that of a June beetle. The weight of a wild crop is often much increased by the sand which gets into the holes eaten out by the grubs, but their operations are usually not extensive †

The writer has also observed a very few roots covered with a white fungous growth and affected with a kind of bleeding rot near the crown. On the whole, canaigre is remarkably free from insect and other enemies.

CANAIGRE TANNING MATERIALS.

Chemical Composition of Roots.—The roots of canaigre contain a varied assortment of vegetable principles. Besides water, which comprises about two thirds of their weight, various workers have found them to contain rheo-tannic acid, red and yellow coloring matters, sugar, gum, resins, albuminoids, starch, woody fiber, certain plant acids and mineral ash. Of these ingredients, tannic acid, part of the resinous and coloring matters, sugar, and to some extent starch and soluble ash, all affect the leather making process.

Distribution of Tanning Materials.—Canaigre tanning materials, by which is meant both tannic acid and those coloring matters which are taken up by raw hide, are found throughout the plant—in the leaves, blossom stalks, and seeds, but chiefly in the roots, which commonly contain from eight to ten per

†I am indebted to Professor J. W. Toumey, of the Station for suggestions and criticisms under this head.

cent in the green state. The distribution of these tanning materials throughout the root is not uniform. The older parts, consisting of the heart and the outer (unweathered) bark, are richest in tanning materials, while the zone of new growth formed each year contains distinctly less. Two samples of wild roots divided into bark, heart and new growth gave in dry substance,*

1. Bark..	39.77 per cent.	New growth..39.74	Heart..43.55
2. " ..	39.30	" " ..38.72	" ..43.11

There is usually no marked variation in the amount contained in tops and bottoms of roots. In thirteen samples of two year old roots taken throughout the summer during the dormant period the top halves averaged 26.6 per cent and the bottoms 25.4 per cent of tanning materials. Ten samples of young roots taken in December and January at the beginning of the period of growth averaged, in tops 24.86 per cent, in bottoms 25.80 per cent. At other times the amounts varied slightly in favor of either tops or bottoms. In selecting roots for propagation or for seed production a very accurate sample may be obtained by cutting crosswise through the top, middle and bottom of the root with a circular punch about half an inch in diameter. This method has given us closer agreement between the sample and the remainder of the root than the practice of cutting off and analyzing the lower half, although the latter gives results which compare quite well with each other. In either case the roots are not injured for growth, the crowns of divided roots growing vigorously and in time replacing the lower removed portions.

Formation of Tanning Materials.—The history of the formation of the tanning materials was carefully observed at Tucson during the season of '94-'95. For this purpose thirty-six lots of twenty-five one year old roots each, weighing nearly two pounds per lot and as uniform as possible in age and condition, were planted November 26th, 1894 and kept under close observation for the ensuing ten months. The lots were all grown under as uniform conditions as possible, excepting Nos. 20,

*All percentages on tanning materials, etc., in this bulletin, unless otherwise noted, refer to water free roots. To reduce them for the average of green roots, divide by three.

TABLE II.

Chemical Life History of Canaigre.

				IN OLD ROOTS.					IN YOUNG ROOTS.					IN LEAVES.	
Number of sample.	Date when dug.	Condition of lot.	Weight of seed-roots, green, in grams.	Water in green roots.	Averaged in sets of three.	Tannins in water-free substance.	Averaged in sets of three.	Non-tannins in water-free substance.	Water in young roots.	Tannins in water-free substance.	Averaged in sets of three.	Non-tannins in water-free substance.	Weight of new roots, green, in grams.	Tannins in water-free substance.	Tannins in green leaves.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
				%	%	%	%	%	%	%	%	%		%	%
43	Not planted	Sample	820	53.83		25.87		15.99							
42	" "	"	820	55.01		25.77		16.70							
41	December 8, 1894	Sprouting	876	57.97		25.16	25.60	16.97							
40	" 15, "	"	856	61.32		26.04		16.85							
39	" 22, "	"	877	61.52		25.36		16.70							
38	" 29, "	Up and growing	907	64.00		25.72	25.71	16.56							
37	January 5, 1895	Sprouting	897	62.72		26.07		16.63							
36	" 12, "	Up and growing	963	66.01		23.35		16.20							
27	" 19, "	" " "	936	63.30	64.01	24.68	25.38	16.10							
18	" 26, "	" " "	972	64.82		25.34		15.49							
9	February 2, "	" " "	1016	67.22		26.41		17.24							
35	" 9, "	" " "	983	66.91	66.32	27.53	26.43	16.10							
26	" 16, "	" " "	968	67.35		26.53		17.26							
17	" 23, "	" " "	980	68.08		28.30		15.79							
8	March 2, "	" " "	1014	69.33	68.25	28.28	27.70	15.02	86.3	1.91		36.04			
34	" 9, "	" " "	1055	70.05		27.30		14.20	84.6	6.41		32.39		6.62	.70
25	" 16, "	" " "	990	67.72		25.56		14.37	81.9	8.84		28.64		6.24	.69
16	" 23, "	Blossoming	1005	68.87	68.88	27.07	26.64	15.26	80.4	9.05		31.11		5.94	.67
7	" 30, "	"	1104	69.90		27.77		15.04	77.4	12.53		24.11		5.49	.64
33	April 6, "	"	1107	67.35		24.18		17.00	72.2	16.28		22.79		4.62	.58
24	" 13, "	"	1091	66.30	67.85	24.34	25.43	15.92	69.0	19.21	16.01	20.07		8.15	1.04
15	" 20, "	Leaves dying	1107	66.88		25.65		16.02	69.8	19.01		20.02		9.40	1.27
6	" 27, "	" "	1235	67.10		26.42		14.89	69.4	21.16		18.62		8.18	1.29
32	May 4, "	" "	1060	67.00	66.99	26.95	26.34	12.64	69.7	19.28	19.82	17.55		9.62	1.45
23	" 11, "	" "	1254	66.98		25.67		12.32	67.0	22.24		17.50	2248	8.13	1.60
14	" 18, "	Leaves dead	1226	68.26		26.36		12.62	69.2	21.64		15.10	1190	7.91	
5	" 25, "	" "	1114	68.42	67.89	27.91	26.65	12.78	68.9	23.34	22.41	13.58	1236	7.14	
31	June 1, "	Plant dormant	1184	68.04		26.20		11.86	68.9	21.38		12.97	885		
22	" 8, "	" "	1701	67.06		25.07		13.98	68.5	23.67		14.26	5060		
13	" 15, "	" "	1072	66.03	67.04	25.59	25.62	11.42	67.8	21.83	22.29	14.23	1224		
4	" 29, "	" "	1183	67.00		27.34		12.69	70.1	24.85		14.99	1940		
30	July 13, "	" "	851	64.85		26.29		13.08	69.1	24.39		14.48	1019		
21	" 20, "	" "	1279	66.62	66.16	25.69	26.44	13.18	68.4	24.23	24.49	15.04	4065		
12	August 3, "	" "	1118	65.15		23.90		11.92	69.7	24.47		16.28	1165		
3	" 24, "	" "	1102	67.53		28.05		12.84	71.6	23.25		16.68	2137		
20	September 6, "	" "	1331	66.05	66.24	26.97	26.31	10.46		25.33	24.35	14.59	5063		
11	" 21, "	" "	1202					11.28	71.5						

Average for water in seed roots (Col. 5 after Dec. 8th.) 66.5 per cent.
" " " " young roots after maturity (after April 13, Col. 10) 69.3 per cent
" " tanning materials in seed roots, 1-2 years old, (Col. 7) 26.19 per cent.
" " " " " new roots, after maturity (Col. 11, after May 11th) 23.38 per cent.
" " " " " leaves after maturity (Col. 15, April 13 to May 25th) 8.36 per cent.

21 and 22, which were irrigated seven times as compared with four times for all the others. They were dug consecutively each week during the whole growing season and also at intervals throughout the ensuing summer. The old roots, new roots, and leaves (when present) of each lot were separated and prepared for analysis. The roots were planted too late for a full season's growth, the soil was poor, and seed roots sometimes faulty but the figures, taken in connection with other results, are suggestive, in fact the irregularities of the lots have in themselves led to some interesting observations. The results are shown in Table II, which, in connection with the stage of growth and condition of roots, contains the data for water, tanning materials, and non-tanning substances soluble in water, for both old and new roots, during the period from November 26th, 1894 to September 21st, 1895. The tanning materials of the leaves are also noticed.

As to the increase of tanning materials during the year, it appears in columns 7 and 8 of Table II that they remain pretty constant throughout the growing season with, however, a small but distinct increase after the plants become established in vigorous growth. The amount of this increase in mature roots from year to year was further shown by taking four samples of wild roots comprising every age up to about five years, dividing the samples as nearly as possible into successive year's growth, and analyzing. It was found that the average increase of tanning materials from year to year in ten instances was 1.64 per cent (in water free material). In one set of cultivated samples the averages of the first and second year's roots differed 2.64 per cent. This indicates a small but constant increase in the per cent of tanning materials from year to year, but holds true only so long as the roots retain their vitality. When they die the tanning substances quickly disappear. Although the percentage does not increase remarkably from year to year, the roots themselves become larger so that the actual amount of tanning materials is

---

Note,—All the tanning material determinations referred to in this bulletin were made by the hide powder method of analysis, somewhat modified to suit the substance dealt with. The inaccuracies of the method were reduced as far as possible by an absolutely uniform routine and it is believed that none of the individual figures on tanning materials are subject to a comparative error of more than .4 per cent, while in averages it is inappreciable.

tual amount of tanning substances in roots containing them, although the percentage may sometimes increase because of the withdrawal of starches and sugars from the roots at this period of growth.

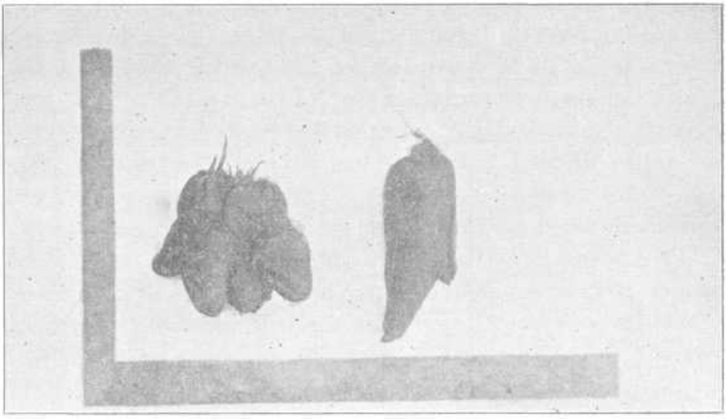

Fig 1. Two large roots (38 and 26 oz.) from 3 year old plantings at Phoenix. Average tanning materials for crop, 30.4 per cent.

Effect of Irrigation.—In order to note the effect of extra irrigation upon yield and percentage of tanning materials, Lots 20, 21 and 22 were given about twice as much water as the others. The yield of new roots (from Column 14), their average weight, and the percentage of tanning materials for these, and the other plantings in column 14 receiving less water, are as follows:

	Average yield in grams.	Average weight of roots in grams.	Average per cent tanning materials.
Three best lots............	4729	62	24.41
Nine common lots.........	1449	29	23.04

From this it appears that although the lots grown with abundance of water were over three times as heavy as the others, the per cent of tanning materials was more than maintained. This observation is confirmed on a larger scale by comparisons between cultivated roots grown at Phoenix and Tucson and the wild stocks from which they came. Two large samples of cultivated roots from the Phoenix Station, one to three years old, grown on adobe soil with plenty of water most of the time, and with many of the roots weighing a pound or more, gave 30.61 and 30.18 per cent of tanning materials (Fig. 1). The average for nine samples of car load lots of wild stock shipped from the same locality, was 30.84 per cent. From these car-load lots the younger roots had been taken so that 30.84 per cent is really too high a figure for the complete crop. Also, the average at Tucson for tame roots, up to two years of age, in stock which has been cultivated for four years, is about 25.5 per cent (Fig. 2). Two large, carefully taken wild samples of the same age and stock gave 25.39 and 26.56 per cent (Fig 3). In all cases the tame roots average larger than the wild ones and, further, analyses of five particularly large cultivated roots, one and two years old from Phoenix showed them to average 27.5 per cent of tanning materials, which, allowing for less age, indicates a fair maintenance of quality. It will also be seen in Table II, columns 11 and 14 after May 11th, that the prosperity of indi-

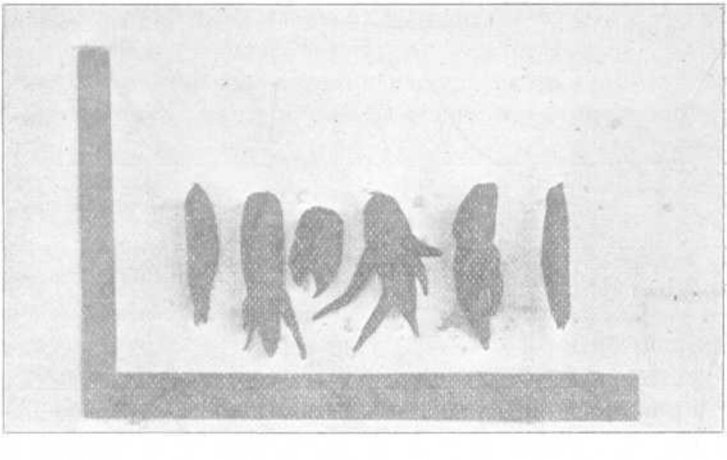

Fig. 2. Cultivated roots from Rillito stock, 1 year old containing 25.33 per cent tanning materials.

much greater. For instance, in the above table the seed roots of Lot 22, June 8th, 1895 contained 140.5 grams of tanning substances as compared with 89.5 grams in the check Lot 43.

This increase in percentage from year to year makes it necessary, in comparing the tanning materials contained in different stocks, to take roots of corresponding age. In this way specimens may be selected for propagation whose differences are not in part due to age. For this purpose roots at the end of their first growing season are best, since they can then be distinguished more certainly.

Effect of Dormant State.—In the new roots, the increase in tanning materials (Columns 11 and 12) is very rapid until the plants become dormant in the beginning of May. After this time they at first still show a slight average increase (Column 12) but finally stand still for the rest of the summer (after June 15th). The old roots (Column 8) after the beginning of May remain very constant in tanning materials. Further observations on the behavior of the root during its dormant state were made by taking five samples of new roots, analyzing half of the lots immediately, burying the rest in shaded ground for an average period of 4½ months during the summer, and then analyzing them also. The five samples immediately analyzed averaged 23.19 per cent; those kept through the summer averaged 24.78 per cent, showing a slight increase in every case, and an average increase in all instances of 1.59 per cent. These facts are somewhat contradictory but on the whole seem to show a tendency to increase of tannins in dormant young roots,—an observation which is said to hold true for other tannin containing roots. Other things equal, it appears that the best time for harvest should be in late summer or early fall. Reckoning at 5 cents a pound for 50 per cent extract an increase of 1½ per cent tanning materials in dry substance from ten tons of roots would be worth about ten dollars.

Effect of Sprouting.—During December and January, while the plants were getting under way (Columns 7 and 8) the tanning materials remained very constant. According to some investigators, sprouting should have no effect upon the acvidual lots as shown by the yield of new roots has no fixed relation to the percentage of tanning materials.

These facts, so far as they go, show pretty clearly that irrigation, with the consequent increase in size of roots does not seriously lessen the percentage of tanning materials. This tentative conclusion does not fully agree with the statement in Bulletin No. 18, which was founded upon analyses made of samples subsequently known to be unsatisfactory. If confirmed by future experience this item will be of great importance in connection with the culture of canaigre.

Nevertheless, there are remarkable variations in the amount of tanning materials in roots from different localities. During the year we have encountered a range from 18.17 per cent to 32.56 per cent in new roots. This may in part be due to strains of roots, or to local conditions. It is known that tannins are not produced in the leaves of plants at night or on cloudy days, and even in the same tree more tannins are formed in leaves fully exposed to the sun than in those occupying shaded positions. It is also said to be accepted among European tanners that bark grown on southern exposures has better tanning power than that coming from more shaded situations.

In this connection it was noticed that the sample of canaigre containing 32.56 per cent of tanning materials came from an arid, sandy, southern slope fully exposed to the sun. The stock which analyzed 25.39 and 26.56 per cent tanning materials was about the same age and from the same locality but was somewhat shaded by mesquite and bushy undergrowth. A sample of new roots grown at Lake City, Florida, from Arizona and New Mexico stock, gave 24.74 per cent tanning materials but the sunshine record of that region is not obtainable for comparison with that of Arizona. It may be found that the tannins of canaigre are practically affected by the amount and intensity of sunshine in the locality where grown. If so, the arid Southwest, "the land of sunshine," possesses unmistakable advantages for canaigre culture. During the last growing season the sunshine record for Southern Arizona was 84 per cent of the theoretical amount. At present, however, there are no definite data

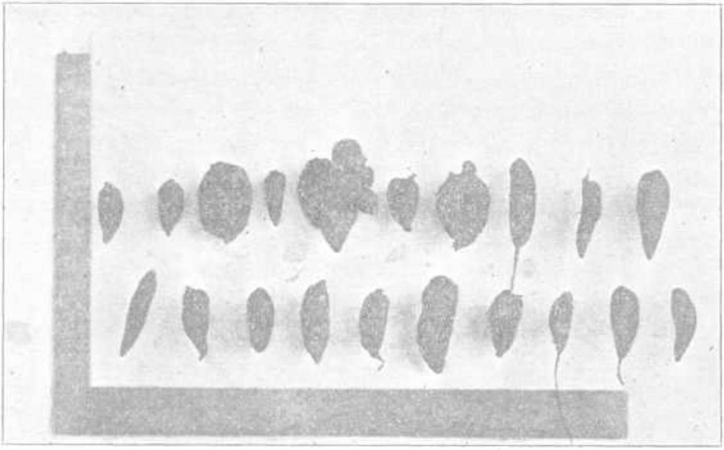

Fig. 3. Wild stock of all ages from Rillito Wash, near Tucson. Younger roots contain about 26.0 per cent tanning materials.

as to the effect of this condition of growth upon tanning substances in canaigre.

In columns 15 and 16 of Table II the leaves also are seen to contain about one third as much tanning materials by percentage as the mature roots. The actual weight of the dry leaves is about one fifth that of the dry root system (8 observations of *one year old* plantings) so that approximately one fifteenth of the tanning materials of the mature one year old plant are contained in its leaves. This probably cannot be economically extracted, and the large amount of ash in the leaves (about 25 per cent) would make it advisable to return them to the land.

It has been observed in general, that in tannin producing plants, the leaves are the laboratory where, for the most part at least, the tannins are formed under the influence of light and with assimilation of carbon dioxide. From there the tannins migrate downward into the stems and roots of the plant where they are stored in the cellular tissue. In this position they usually remain. They are not, in most instances at least, carried up into the young shoots of the plant when growth recommences as is the case with those carbohydrates which contribute to the formation of new tissue. In this respect the tannins of canaigre differ from the sugar of beets, which may be partly lost if weather conditions induce the ripened beets to recommence growth. After being stored in the parenchyma tissue the tannins are liable to slow changes which result, apparently, in the formation of the red coloring matters which are observed in the heart and bark of many plants and trees, canaigre among the number.

The tannins are variously supposed to prevent consumption of plants by animals, and to hinder decay. The first explanation of their use serves especially well for canaigre, which grows in a region where forage for herbivorous animals is often extremely scarce, and where the plant would be liable to extermination if it were palatable.

Destruction and Loss of Canaigre Tanning Materials.—Heat, air, and fermentation all cause loss of canaigre tanning materials. Because of the action of heat and air, it is essential in preparing samples for analysis to secure quick drying at as low a temperature as possible. For this purpose we have found that the thinly sliced roots should be dried in an oven at about 130 degrees F. or, during warm weather, in the open air. The accuracy of this method is shown by comparing the analyses of portions of roots dried in the oven with those of their duplicate portions dried in a vacuum at ordinary temperature, and from which the action of heat and air were therefore excluded. The duplicates all agreed very closely, the averages being:

	Tanning materials.
For three portions of roots dried in oven at 130° F.	25.74%
" " duplicate portions in a vacuum at ordinary temperature	25.69%

—showing the regular samples not to have suffered loss when prepared in our standard way.

At high temperatures the tanning substances are rapidly destroyed, either in the green root or in solution, in the air or in an atmosphere of other gases such as steam, hydrogen, and carbon dioxide. In one case a root was divided into three portions, the first portion prepared as usual, another dried in air

10 hours at steam heat, and the third in hydrogen for 12 hours at the same temperature, with results as follows:

	Tanning materials.
Sample prepared as usual	25.07%
Dried 10 hours in air at steam heat	17.73%
Dried 12 hours in hydrogen at steam heat	17.30%

When dried whole, the roots also lose heavily in tanning substances. One experiment gave:

For root sliced and dried as usual	25.07%
For duplicate portion dried whole at ordinary temperature	23.35%
For duplicate portion dried whole at steam heat	6.62%

Grated samples also appear to give a slightly less percentage of tanning materials than sliced, due apparently to the action of air upon the increased surface exposed by this method of preparation.

Average of two samples, sliced	23.51%
Average of two duplicate portions, grated	22.05%

In solution, and at or near boiling point, a similar loss of tanning materials occurs. At the same time, insoluble substances are formed whose presence is undesirable in the commercial extract. These insolubles are light in color when air is excluded from the hot liquors by hydrogen, but are of a strong red or brown when formed in presence of air. They are largely soluble in hot tannic acid solution and alcohol, and somewhat so in hot water, but they are commercially troublesome and their extensive formation to be avoided.

Fermentation occurs when the green roots are deeply piled. The water extract also ferments readily. This is due to the starch in the roots and to sugar in both roots and extracts. Analysis of fermented liquors has also shown very considerable loss of tanning materials at the same time. In artificially frozen samples we failed to observe any loss of tanning substances.

These facts are all of practical value, especially in connection with the manufacture of extract. The effect of heat and air, for instance, is shown on a large scale in Table VII by the analysis of two samples of canaigre extract kindly furnished by Mr.

C. B. Allaire from his factory at Deming, New Mexico. Extract No. 1 is their regular product, evaporated in vacuum apparatus to about 80 per cent of solids. No. 2 is a similar product which had been accidently raised nearly to steam heat, in presence of air, for about six hours. The loss of 3.88 per cent of tanning materials is plainly associated with the corresponding gain of 5.02 per cent of the undesirable insolubles.

The behavior of roots dried whole would also indicate that a harvested crop should not be allowed to dry out in bulk. There is no danger of this as long as the roots remain in the ground, even in the driest season. In columns 5 and 10 of Table II it is noticeable that throughout the long hot summer, although not irrigated, the matured roots lost a scarcely perceptible amount of water.

Coloring Matters.—Both yellow and red coloring matters are found in canaigre. The yellow substance is most conspicuous in young roots. It is found chiefly in a central zone and in a narrow layer under the outside skin. It is contained in old wild roots also, and may be dissolved out with ether, but its presence is here obscured by the stronger red color. It is contained in comparatively small quantity (.5-1%), partly dissolves in water, and is absorbed by raw hide during the tanning process, imparting a light yellow color desirable for some grades of leather.

The red coloring substances are most abundant in wild roots, especially those whose chunky form and small size indicate slow and difficult growth. Cultivated, and young wild roots do not show them in any quantity. It is maintained in a general way that abundance of red color is associated with large percentages of tannic acid. This also seems to be true of canaigre for, notwithstanding that the entire wild crop appears to be no richer in tanning materials than the whole cultivated crop, the roots thus far noticed which were individually richest in tanning materials were very red.

According to the proportions in which the different coloring matters of canaigre are contained, separate roots may range all the way from a clear yellow to a pronounced red. The amount of red coloring matters soluble in water is variable, but often very considerable (10 per cent?). Their desirability depends upon the kind of leather to be produced. They are objected to by tanners of certain grades of goods. This objection, however, if valid, will disappear with the use of cultivated roots, since the tame crop, even up to three years of age, contains very little red color.

Red color may be artificially formed by the action of air and heat upon both roots and extract. Light also causes a deepening of color on exposed surfaces.

Soluble Non-tannins.—These are the substances, soluble in water, which are not absorbed by raw hide. They are largely composed of albuminoids (substances containing nitrogen) and sugars. Their amount during the growth of the canaigre plant is shown in Table II, columns 13 and 9. It is seen that at first the young roots contain a large amount of these substances (36.04% in dry material), but that they gradually decrease in quantity as the roots grow older (to 10.46%).

Sugar plays an important part in the process of tanning, since its fermentation results in the formation of certain organic acids, chiefly acetic, which swell or "plump" raw hides and thus help to produce thick and heavy leathers.

The amounts of sugar contained in two large samples of wild and tame roots, water free, were:

In tame roots, 1-3 years old........................16.25%
In wild roots, all ages..............................16.03%

This sugar largely finds its way into the extract, as is shown in Table VII, and is an important factor in the management and results of the tanning process.

CANAIGRE BAGASSE.

After extracting canaigre with water, about 50 per cent, more or less, of the solids remain behind. This residue, or bagasse, contains all of the starch and woody fibre of the root, with portions of the mineral ingredients, albuminoids, sugars, and coloring matters, together with a little of the tannic acid.

Various uses may be surmised for this material, such as for stock-food, fuel, or fertilizer. There is little likelihood of its use for stock-food, as in the case of beet chips, although analysis indicates a considerable quantity of presumably nourishing material.

An analysis of the bagasse prepared by extracting the green sliced roots with warm water is stated in Table III in comparison with an analysis of beet chips from the Nebraska station.

TABLE III.

Food Analysis of Canaigre Bagasse.

Composition of dry matter.	Canaigre bagasse from 1-3 year old roots.	Sugar beet chips.
	%	%
Fat	.71	.68
Protein	7.94	9.45
Nitrogen-free extract	76.98	62.62
Crude fiber	12.07	22.40
Ash	2.28	4.85

Apparently the bagasse has the advantage of beet chips in containing more starch, sugar, etc. (nitrogen free extract) and decidedly less crude fiber and ash. The material is, however, apparently uninviting, and of doubtful utility in this direction. The only portion of canaigre observed to be of food value is the base of the blossom stalk. This is agreeably sour and we have seen range cattle eating it with relish.

As a fuel, canaigre bagasse apparently has considerable value. Table IV states the heating and evaporative power of three samples in comparison with an average soft coal, and with mesquite wood, which is a leading fuel in the arid Southwest. The comparison of fuel values is best made in the column of evaporative powers, which in each case means the number of pounds of boiling water which can be evaporated, theoretically, by one pound of dry fuel.

TABLE IV.

*Fuel Value of Canaigre Bagasse.**

	Calculated to dry material.	
	Calories per gram.	Evaporative powers.
Bagasse from 1 year roots	4826	8.99
" " 2 " "	4753	8.85
" " 1-3 " "	4702	8.76
Average for above	4760	8.87
Average soft coal	7000	13.00
†Mesquite wood	4352	8.10

Compared with soft coal, canaigre bagasse therefore appears to be as 8.87 to 13.00 in evaporative power, or about two-thirds, while it is even better than mesquite wood. It is customary in tanneries to burn spent tan-bark, but it is first necessary to run it through a press in order to expel water and put it in suitable mechanical form for burning. Calculating on 50 per cent of the dry matter as bagasse, an acre crop of ten tons of green canaigre (66⅔% water) would give 3333 pounds of combustible residue, equivalent in heating power to something over a ton of ordinary soft coal. It is possible that in view of the costliness of fuel in the Southwest, the bagasse may be utilized in this way in the extract factories of the future.

Probably an excellent use for canaigre waste is as a fertilizer. When the wet bagasse is piled it ferments vigorously, owing to its starchy nature, and shortly rots down into a black mould, rich in organic matter, and containing part of the nitrogenous and mineral constituents which the crop removes from the soil.

*These fuel values were determined by Thompson's calorimeter, with the usual corrections.

†From U. S. 10th census report.

The return of this material to land would partly make good the loss of these constituents, and also correct the deficiency of organic matter which is characteristic of arid region soils, thereby making them more retentive of water and of better tilth. In order to find how much of the fertilizing constituents were withdrawn from the roots by the process of extraction, a large sample of a two year old crop was sliced and extracted with pure water. The extract was then evaporated, burned, and the ash analyzed. It was found that in actual amount about two thirds of the potash, and four fifths of both nitrogen and phosphoric acid were removed by water extraction, but the residual organic matter would, as mentioned before, constitute a redeeming element of value.

THE RELATION OF CANAIGRE TO THE SOIL.

The nature of the drain made by canaigre upon the soil is shown in Table V by two complete analyses of ash, together with part of the figures for the sugar beet. The samples were prepared from roots grown under the most diverse conditions. No. 1446 is from a cultivated crop, 1-3 years old, grown at Phoenix, Arizona, on somewhat alkaline adobe soil. No. 1447 was prepared from wild canaigre of all ages dug at Congress, Arizona, from a sandy flat. The analyses were executed by Mr. Mark Walker of the Arizona station.

From this table it appears that, as compared with the ash of sugar beets, the proportion of potash in canaigre ash is slightly less, while that of phosphoric acid is very much smaller. Nitrogen is less in the beets than in the younger sample of canaigre. In an analysis made at the California station, the percentage of potash in canaigre ash is much less than in beets (28.74 and 49.4 per cent), while that of phosphoric acid is more (18.19 and 14.30 per cent). In this analysis, the nitrogen of canaigre is also in greater amount (1.93 and .87 per cent). These observations do not agree well with the figures in Table V, but this may be due to differences in conditions of growth, or in the age of roots chosen for examination. In order to get a better idea of the actual draft made on the soil by roots of an age which would probably be most suitable for harvesting in practical cul-

TABLE V.

Composition of Canaigre Ash.

	No. 1446. Cultivated.	No. 1447. Wild.	Sugar Beets (Average 43 analyses).
	%	%	%
Dry matter in green root	33.3		19.18
Nitrogen in dry root	1.79	.73	1.09
Crude ash in dry root	4.27	4.61	
Carbon and sand in crude ash	5.15	4.51	
Carbon dioxide in crude ash	11.26	15.79	
Pure ash in dry root	3.57	3.67	4.04
In pure ash:			
Potash (K_2O)	45.22	42.58	49.28
Soda (Na_2O)	4.33	1.56	7.67
Lime (CaO)	10.76	21.04	7.07
Magnesia (MgO)	12.80	8.94	8.07
Alumina (Al_2O_3)	.48	1.52	
Iron oxide (Fe_2O_3)	.39		
Manganese oxide (Mn_3O_4)	.11	.19	
Phosphoric acid (P_2O_5)	7.34	10.25	14.95
Sulphuric acid (SO_3)	10.06	7.71	5.84
Soluble silica (SiO_2)	1.03	2.28	
Chlorine (Cl)	9.62	4.74	4.83
	102.14	100.81	
Excess of oxygen by chlorine	2.16	1.07	
Total	99.98	99.74	

ture, partial analyses were made of ash from four samples of young roots, 1 to 3 years old, and grown in different situations. The average results are stated in Table VI in connection with those for beets and are calculated to actual pounds of the various constituents per crop of ten tons of fresh roots.

TABLE VI.

Composition of Canaigre Ash—Continued.

	Canaigre; average for 4 crops of young roots 1-3 years old.	Sugar beets; average of 43 samples.	Pounds of constituents withdrawn by crop of ten tons of canaigre.	Same for ten tons sugar beets.
	%	%		
Dry matter in crop	33.3	19.18	6667	3836
Nitrogen in dry matter	1.85	1.09	*123.3*	*41.8*
Pure ash in dry matter	4.13	4.04	275.4	154.9
In pure ash:				
Potash (K_2O)	40.89	49.28	*112.7*	*76.4*
Soda (Na_2O)	3.71	7.67	10.2	11.9
Lime (CaO)	11.06	7.07	30.5	11.0
Magnesia (MgO)	11.34	8.07	31.2	12.5
Phosphoric acid (P_2O_5)	13.27	14.95	*36.6*	*23.2*
Sulphuric acid (SO_3)	8.50	5.84	23.4	9.0
Chlorine	7.78	4.83	21.4	7.5

Owing largely to the much greater percentage of dry matter in canaigre, the tax is heavier in every particular except that of soda. Ton for ton, canaigre demands three times as much nitrogen, and draws one and a half times as heavily on potash and phosphoric acid. In comparison with beets, and at current prices for fertilizers, it would cost about twice as much to make good the loss caused by canaigre.

These facts all indicate that the problem of fertilization in canaigre culture will be a serious one. This is especially true of nitrogen. It is possible that this drain may be made good by green-manuring with nitrogen assimilating crops grown on the land during its idle summer interval.

THE CANAIGRE INDUSTRY.

The canaigre industry is properly concerned with three facts:

1. The demand for canaigre tanning materials.
2. The preparation of extract.
3. The culture of the plant.

The Utility of Canaigre in Tanning,—As regards the value of canaigre tanning materials, the writer has been at some pains to obtain the verdict of practising tanners, and finds that the earlier favorable opinions of tanning chemists have been excellently supported by the experience of the trade From various sources it is learned that canaigre chips and extracts have been successfully employed, either alone or in connection with other tanning materials, for the production of a remarkable variety of leathers, including both heavier and lighter grades.

According to the statements of different tanners it is employed in the production of:

1. "Patent and enamelled leathers for the carriage, saddlery, and upholstery trades."
2. "Patent and enamelled leather" for fine shoes.
3. "Carriage covers and dash board leather."
4. "A high grade of carriage and furniture leather" and "a fair grade of patent shoe tipping."
5. "Upper, grain, or similar light leather."
6. "East India kips finished as waxed leather."
7. "Yellow leather for mittens, horse hides, butts, kangaroo, glazed kid, and other fine shoe leathers."

8. "The heaviest sole and harness leather, and the lightest calf and sheep, with best results for all kinds."

The application of canaigre to such a variety of results is due to various causes such as the peculiar nature of the union between the hide and the tannins, the effect of color, and that of sugar. With proper management these factors may be so controlled as to produce one or another result. Some special qualities in leather which may be secured by its use appear from the following extracts:

1. "For light leathers it gives excellent wearing or strain resisting qualities."

2. "It gives split leather far greater strength than either gambier or hemlock liquors."

3. "New canaigre liquor will give a fair color and produce a very fair leather in cool weather."

4. "The stock plumps very much and fills well after changing into other tanning liquors" and again, "Canaigre plumps the grain."

5. The "permanence" and "speed" of canaigre tannage is also noticed by other correspondents.

Of course objections and differences of opinion have been encountered. This is to be expected during the introduction of a new material and may sometimes be due to conservatism, sometimes to lack of knowledge concerning the peculiar handling required by canaigre. The objections have been arranged for consideration as follows:

1. Starch is said to be troublesome by some.

2. *Red* canaigre color is generally disapproved, though some tanners state that they secure good results with it.

3. The ready fermentation of canaigre liquors is a source of difficulty to many tanners.

As to starch, the objection, if valid, will disappear with a proper system of leaching the chips, or by the use of extract. As is noted in Table VII two samples of commercial extract failed to show a trace of starch.

As to color, there are various opinions, largely according to the nature of the product sought for. In the case of patent and enamelled leathers, which are submitted to special finishing processes, it is stated that the color does not affect the result. Where light colored leathers are desired objections have been encountered, although one prominent tanning chemist says that with proper management canaigre will yield as fair a product as oak.

The color problem will disappear with the use of cultivated roots since they do not contain red matters in any quantity, and the yellow color which they do contain is generally stated to be highly desirable for all light or yellow leathers.

Fermentation, which is due to the large amount of sugar in chips or extract, may result disastrously if allowed to proceed too far. It may be controlled by the use of antiseptics or "tan sweeteners," and by steaming, and when kept within limits is one factor in the production of thick leathers. This is because the organic acids resulting from the fermentation of sugar separate the fibers of the hide and thereby swell or "plump" it, fitting it to take on weight in the later stages of tanning. Cool weather also lessens the difficulty with over-fermentation.

Extract Manufacture:—The demand for canaigre, founded upon the above considerations, is at present supplied by the wild root, partly in the form of dried slices or chips, partly as extract. The extract is mostly consumed in this country, while the chips are largely used in Europe. The manufaeture of extract will probably be an essential feature of the proposed industry, the object being to economize freights and put the product in convenient form for handling and keeping.

Owing to the destructible nature of tannins, any process of leaching and concentration implies careful provision against the excessive action of heat and air. A soft pure water supply for leaching the roots is also essential since the presence of sediments, peaty matters, and certain mineral salts, especially chlorides and iron compounds, is objectionable. Lime or magnesia hardness causes loss of tannic acid and an increase of insolubles. The average quality of commercial extract, as well as the adverse effect of heat and air, is shown in the following table, which has been referred to before:

TABLE VII.

Effect of Heat and Air on Canaigre Extract.

	No. 1. Normal extract.	No. 2. Overheated extract.	
	%	%	
Water.................	20.00	20.00	
Tanning materials.........	49.94	46.06	Loss, 3.88%
Non-tannins sol. in water...	28.11	27.22	
Insolubles................	2.02	7.04	Gain, 5.02%
Totals...............	100.07	100.32	
Ash in extract............	4.70	....	
Sugar in extract...........	11.89	14.98	
Starch....................	none	none	

Aside from the transformation of tanning materials into insolubles by means of heat, and the absence of starch, the amount of sugar is interesting. For every 100 parts of tanning materials, these samples average 28 parts of sugars or acid forming substances. In this respect canaigre extract is very rich, even approaching fir bark extract, which is said to contain about 32 parts of sugars to 100 of tanning materials, and which is distinguished for its plumping qualities.

In answer to inquiries concerning cost of extract factories we have no itemized information. It should, however, be much less than for sugar factories of corresponding size. The leaching machinery is comparatively inexpensive and the crude product does not require the elaborate purification essential in the case of sugar.

Agriculture:—By far the most important commercial problem in connection with canaigre at the present time, is that of its successful agriculture. Upon this depends the permanence of supply and, possibly, the reduction of price also, which shall lead to a general adoption of canaigre by the trade. In New Mexico, Arizona, and Southern California some hundreds of acres have been recently planted, but comparatively little is known as to actual yield and methods of agriculture. Information on these points is largely a matter of judgment based on observation of the habits of the plant and upon experience with similar crops.

The propagation of the plant may be secured in three ways—by sprouts, by seed, and by planting the young roots. As observed by Dr. N. H. Claflin, of the Phoenix sub-station, the sprouts when "broken off close to the root and set as are cabbage plants and sweet potatoes" make an excellent growth.

Seed of good quality may also be obtained, although it is commonly very infertile. In one sample taken from two large transplanted wild roots by the writer, fifty-eight per cent grew (175 out of 300). This shows first rate possibilities since in one random instance it is noticed that high grade beet seed was only seventy-six per cent fertile Seeds produce but one root the first season, so that there would be a delay of one year in a crop started from them. Propagation from sprouts and seeds is not at all likely to prove of importance at present, but in future these methods may be used in developing more valuable strains of roots.

Seeding is best accomplished by means of young roots. These are quicker to grow than old roots, are smaller and more economical to handle, and are apparently more productive than old stock. About nine hundred pounds of one oz roots, planted at one foot intervals in rows three feet apart, are sufficient for an acre. Cultivated seed roots, because of their more uniform age and quality, are to be preferred to wild stock, which has been observed in some large plantings to give a very irregular stand. In the plots shown in Fig. 6, planted with tame seed roots, a stand of about ninety-two per cent was obtained.

Fig. 4. Canaigre plant near end of first year's growth, showing complete root system.
1, seed root; 2, 2, etc., first crop of new roots.

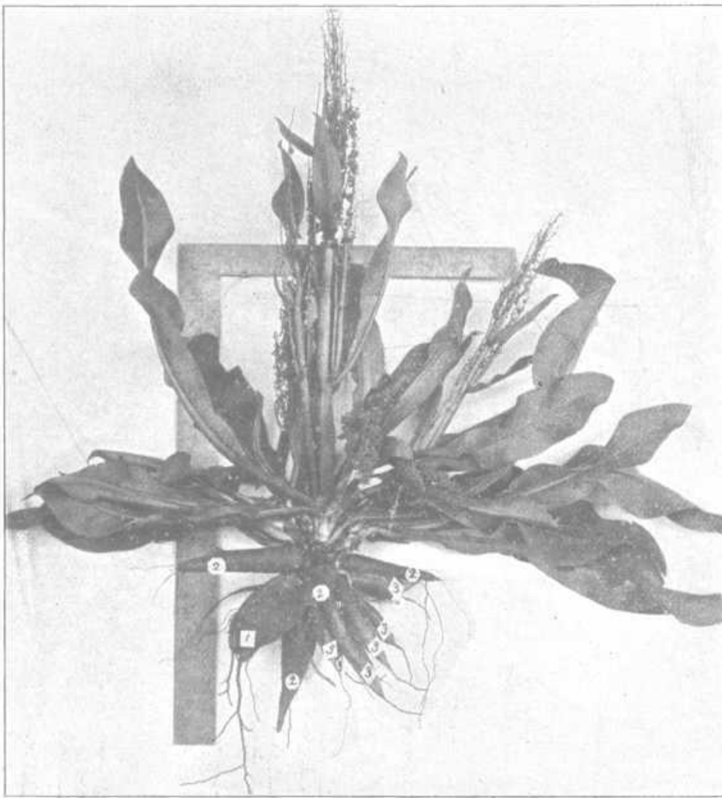

Fig. 5. Canaigre plant at end of second year's growth.
1, seed root; 2, 2, etc., first crop of young roots; 3, 3, etc., second crop of young roots.

The young roots should be dug during their dormant summer period and planted before the cool growing weather comes. Roots may be dug and planted at any time of the year but when they are interrupted after their growth has begun they of course only make a partial development during that year. The application of water in summer, about one or two irrigations in August or September, ought to swell the buds and prepare them for quicker growth later on. Plentiful irrigation is probably advisable since this stimulates growth and, on present evidence, does not lessen the amount of tanning materials as compared with wild stock of the same age. The growing season is also lengthened since well watered plants do not die back so quickly on the advent of hot weather.

During the first year from planting, the seed roots increase to two or more times their original size, and produce a crop of new roots averaging about six to each plant, (average of 500 observations,) although as many as thirteen have been noticed. During the second year of growth the old roots continue to increase in weight, the first crop of new roots becomes larger, and a second crop is developed. A good idea of the plant at the end of the first and second years of cultivated growth may be gained from Figs. 4 and 5. The much larger mass of roots apparent in Fig. 5 at once suggests the question of harvest; whether it should be at the end of the first or second year's growth, or even later. Owing to unfavorable location for the settlement of this question, the Station has as yet been unable to obtain satisfactory data. Certain indications, however, as to yield and the effect of fertilization, are furnished by a plot experiment partly shown in Fig. 6. These two plots are adversely situated as to soil, which is underlaid by "caliche" limestone at about 18 inches and contains only .04 per cent of nitrogen. The plot in the foreground was unfertilized; the one in the background was treated with barnyard manure dug into the irrigation trenches at the time of planting. The plants were set one foot apart in rows three feet apart. The *rates* per acre were as follows:

	Wt. of seed roots when planted.	Increase of seed roots during year.	Wt. of new roots at end of season.
Fertilized plot.....	1130 lbs.	930 lbs.	8220 lbs.
Unfertilized plot...	1110 "	630 "	5820 "

thus making 810 and 580 per cent of new growth respectively. These figures are only of comparative value and do not indicate what the yield should be under favorable conditions.

As yet, the depth and space of planting are a matter of judgment rather than knowledge. A large number of measurements made on thrifty one year old hills have shown the tuber systems to occupy a space of from 5 to 12 inches in diameter, and 6 to 10 inches deep, the small rootlets extending outward and downward from one to two feet further. Allowing for two years' growth, the seed roots should probably not be set less than 12 inches apart. As to depth, roots planted at 3 inches are more prompt to grow and appear more prosperous than those planted at 5 inches. The expense of harvesting a shallow crop should also be less.

Canaigre will grow on any tillable ground, but the relation of actual yield to the kind of soil has not yet been determined. The adobe of the Phoenix sub-station has thus far given unsatisfactory results, and general experience with root crops points, preferably, to a rich sandy soil kept loose by adequate cultivation.

Certain peculiarities of canaigre seem favorable to its agricultural future:

1. It grows in winter, when water is more abundant throughout the arid region. This fact may render possible the reclamation of large tracts of land for which there is not sufficient irrigation in summer.

2. The climate is mild at this season of year and labor is therefore more comfortable and effective.

3. In case of extreme drouth the crop is not lost but the plant simply stops growth and waits for better conditions.

4. Harvesting may occur at any time, the mature crop re-

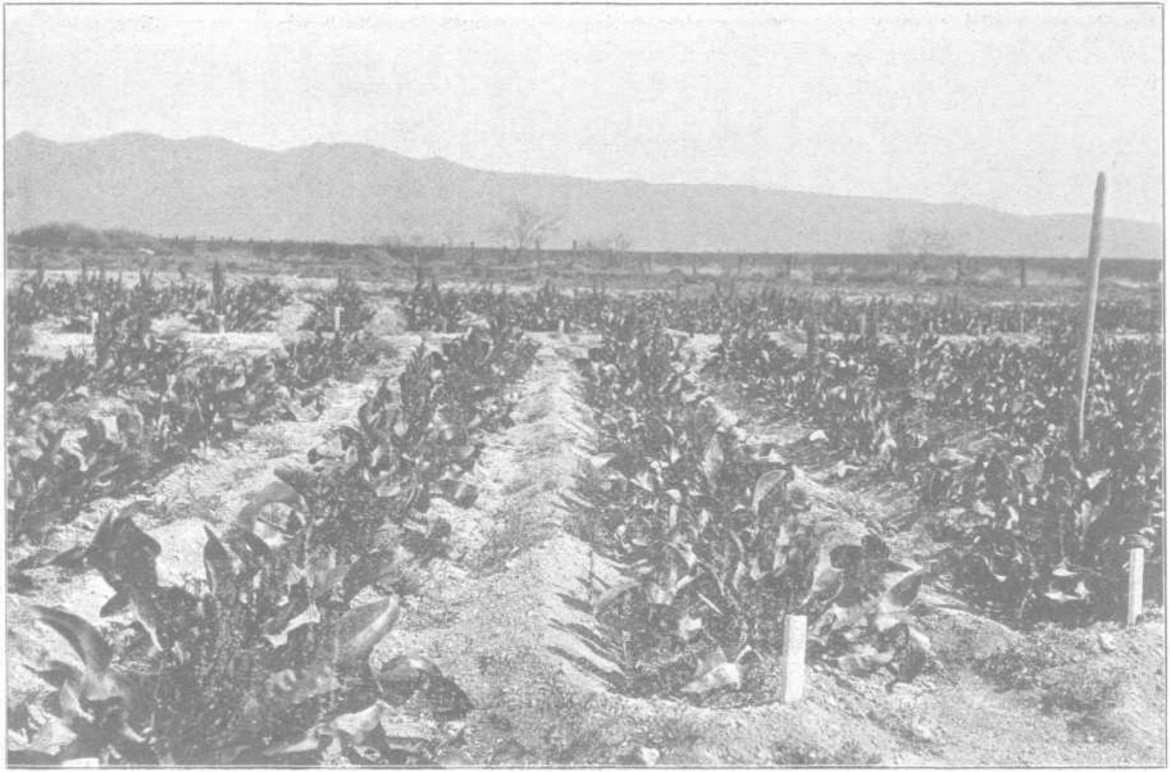

Fig. 6. View of irrigated canaigre plots, taken March 20, 1896, in blossoming season.

maining in the ground indefinitely without injury, and even with a certain amount of improvement.

As to the value of the product, it appears that under existing conditions the objective point is a crop which can be sold at from five to seven dollars a ton. Mr. Chas. B. Allaire, of the Deming Extract Factory, says (May 25th, 1896): "The present selling price of 48% extract is 5c delivered in New York, Liverpool, Hamburg, etc., and if we could sell at 4½c we could sell ten times as much as we are now doing. We are paying $7.00 a ton for wild roots delivered at factory. If we could buy at $5.00 we could make the concession."

Reckoning on a mean value of $6.00 per ton the following comparison with beet culture can be made: The cost of sugar beet culture in the Chino Ranch region is stated to be $25.00 an acre, and the average yield, 11 tons. At $4.50 a ton this leaves a profit of $24.50 an acre to the Chino beet farmer. Accepting Professor Gulley's estimate (Ariz. Ex. Sta. Bull. No. 7, page 40) of $16.50 as the cost per acre of growing canaigre, it would be necessary to grow an annual crop of about seven tons per acre in order to equal the profits of beet culture. Allowing the crop to remain in the ground for two season's growth, and taking out the cost of plowing, planting, and digging for the second year ($7.00), the cost of cultivation for two years would make $26.00. Two years profits ($49.00) plus this cost of cultivation ($75.00 in all) would make it necessary to harvest a biennial crop of about twelve and a half tons per acre. These estimates are merely suggestive and must be taken for what they are worth by those who have practical knowledge of the cost of agricultural operations in the arid region. The yields indicated, as stated before, have not been positively demonstrated, but on the evidence at hand seem fairly probable.

CONCLUSIONS.

1. Canaigre is best adapted to the mild, dry, sunny winter climate of the Southwest. Although it will endure frost, and will grow in rainy regions, it does not promise good results in these uncongenial situations.

2. Canaigre roots and leaves are damaged to some extent by insects, but the plant is not known to be seriously threatened by them.

3. Canaigre tanning materials are found throughout the plant, being in greatest quantity in the central portions of the roots.

4. The tanning materials form rapidly during the first year of growth, showing a small annual percentage increase after the first year, and as long as the root retains its vitality.

5. During the dormant summer period of the plant, the tanning materials seem slightly to increase in younger roots. Sprouting does not affect the quantity of tanning materials. The evidence thus far does not show that irrigation lessens the percentage of tanning materials.

6. Heat, air, and fermentation, acting on either roots or extracts, all destroy canaigre tanning materials.

7. The red and yellow coloring matters of canaigre affect the quality of leather produced. The red matters are less desirable and are formed chiefly in the wild crop. They are not present in quantity in cultivated roots. This fact is considered an improvement in the quality of the root for tanning purposes.

8. The sugar contained in canaigre gives roots and extracts their "plumping" qualities. If properly managed it is a valuable factor in the production of heavy leathers.

9. Canaigre bagasse, properly prepared, should be about equal to mesquite wood in fuel value. When well rotted it ought also to have considerable value as a fertilizer. It promises little as a stock-food.

10. Canaigre draws heavily upon the soil, especially for nitrogen. Its total drain is about twice as costly as that of sugar beets.

11. The utility of canaigre is demonstrated. Properly handled it produces an unusual variety of leathers of excellent quality.

12. The agriculture of canaigre is yet in its experimental stage. A fair estimate shows that it will be necessary to pro-

duce an annual crop of about seven tons, or a biennial crop of about thirteen tons an acre in order to equal the profits of sugar beet culture. On present evidence this yield seems highly probable, but, so far as known, has not yet been demonstrated.

NOTES;—Those who wish to read further on the subject of canaigre will find material in Bulletin 105, of the California station, and in the California Experiment Station Report for 1894-95. Bulletin 7 of the Arizona station, Bulletins 11 and 14 of the New Mexico station, and Bulletin 35 of the Florida station contain additional information. Professor Henry Trimble in his book, The Tannins, devotes a chapter to canaigre, and various articles on the same subject have appeared in the Journal of Pharmacy and The Leather Manufacturer.

For a general discussion of the formation of tannins and their relation to plant structure, the work of Gregor Kraus, Die Physiologie des Gerbstoffs, is most complete and has afforded many suggestions in the course of the work carried out in this bulletin.

The writer is indebted to a number of tanners and tanning chemists who have replied at length to inquiries regarding the merits of canaigre. Among those who have kindly given the results of their experience are Dr. F. H. Heinlein of the Tanning School, Freiberg, Saxony; Professor H. R. Proctor, Yorkshire College, Leeds, England; R. C. & H. B. Good, Tanners, Newark, N. J.; The Grant Tanning Co., Woodstock, Ont.; E. S. Ward & Co., Tanners, Newark, N. J.; W. C. Tiffany, Tanning Chemist, Newburgh, N. Y.; J. H. Fiebing, Tanning Chemist, Milwaukee, Wis.; G. A. Kerr, Tanning Chemist, Columbus, Ind.; and others.

Acknowledgement is due Mr. Mark Walker of the Arizona station for the execution of most of the routine work in connection with analyses for tanning materials.