University of Arizona

Agricultural Experiment Station.

Eighteenth Annual Report.

For the Year Ending June 30, 1907.

(With subsequent items)

Consisting of the Reports of the Departments of

Administration,
Agriculture and Horticulture,
Animal Husbandry, Botany,
Vegetable Physiology and Pathology,
Chemistry, and
Irrigation Investigations.

Tucson, Arizona, December 31, 1907.

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION.

GOVERNING BOARD.

(Regents of the University)

Ex-Officio

HON. JOSEPH H. KIBBEY, . . Governor of the Territory.
HON. R. L. LONG, . Superintendent of Public Instruction.

Appointed by the Governor of the Territory.

MERRILL P. FREEMAN, ... Chancellor.
GEORGE J. ROSKRUGE, . . Secretary
CHARLES H. BAYLESS, A. M., . . Treasurer.
ANTHONY V. GROSSETTA, ... Regent.

KENDRIC C. BABCOCK, Ph. D., . . President of the University.

STATION STAFF.

ROBERT H. FORBES, M. S., . . . Director and Chemist.
JOHN J. THORNBER, A. M., . . . Botanist.
ALBERT E. VINSON, Ph. D., . . . Associate Chemist.
FREDERICK W. WILSON, B. S., . . . Animal Husbandman.
G. E. P. SMITH, C. E., . . . Irrigation Engineer.
WILLIAM B. MCCALLUM, Ph. D., . Associate Botanist.
J. ELIOT COIT, Ph. D., . . . Associate Horticulturist.
WILLIAM H. ROSS, Ph. D., . . . Assistant Chemist.
T. D. A. COCKERELL, . . . Consulting Entomologist.
WILBUR O. HAYES, ... Clerk.

The Experiment Station office and the botanical and chemical laboratories are located in the University main building at Tucson. The range reserves (cooperative, U. S. D. A.) are suitably situated adjacent to and southeast of Tucson. The departments of agriculture and horticulture and of animal husbandry conduct operations on the Experiment Station farm, 3 miles northwest of Phoenix, Arizona. The date-palm orchards (cooperative, U. S. D. A.) are 3 miles south of Tempe, and 1 mile southwest of Yuma, Arizona, respectively.

Visitors are cordially invited, and correspondence receives careful attention.

Samples of water, fertilizers, etc., which are of agricultural interest, and which are received with full information, are analyzed free of charge as time permits.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of your neighbors, especially recent arrivals, who may find our publications useful.

Address, THE EXPERIMENT STATION,
Tucson, Arizona.

LETTER OF TRANSMITTAL.

To His Excellency, Joseph H. Kibbey, Governor of Arizona:

SIR: In accordance with the Congressional act of March 2, 1887, I submit, herewith, the Eighteenth Annual Report of the Arizona Agricultural Experiment Station, for the fiscal year ending June 30, 1907.

Very respectfully,

R. H. FORBES,

Director.

CONTENTS.

White Bermuda onions at Yuma: Above, growing crop, March 22, 1907.
Below: the harvest, ten tons per acre, May 14, 1907.

Eighteenth Annual Report.

ADMINISTRATIVE.

PROGRESS IN RESEARCH.

Facilitated by the increase in resources secured through the Adams Act, established lines of inquiry have made noteworthy progress during the year, and certain additional investigations have been instituted.

Among the contributions of the year to scientific knowledge bearing upon agriculture are: (1) The investigations by Dr. Vinson on the relations of tannin and invertase to the ripening of the date, including theoretical suggestions bearing upon the mode of action of enzymes in general. (2) Along botanical lines Professor Thornber has continued his ecological studies relating to desert forages, while Dr. McCallum has outlined and entered upon his work with the plant diseases increasingly evident in the region. (3) Professor Smith, engaged with the fundamental question of water supply and aided by Southern Pacific Railroad funds contributed for the purpose, has gained much knowledge of the movements, quantity, and availability of the underflow of a typical arid valley. (4) Definite results were apparently developed by Professor Clark from his inquiry into seed selection according to specific gravity, marked improvement in yields being obtained in certain instances from seeds selected on this principle. (5) The technique of the determination of minute amounts of copper in vegetation has been perfected by Mr Free, and a useful study of solubilities of basic copper carbonate in certain solutions of salts and carbon dioxide brought to completion. (6) The investigation by the writer into the effects of mining detritus on crops in the upper Gila region has finally resulted in attributing the damage mainly to the blanketing effects of the detritus rather than to toxicity of associated copper compounds, incidentally affording a fairly satisfactory basis for the settlement

of litigation arising from the presence of these substances in certain irrigating waters of the region.

In the outlying stations, more favorable to work of a demonstrative character, cultural and animal husbandry lines have been continued as usual—sheep breeding at the Station farm, date-palm culture at the Tempe and Yuma date orchards, market gardening trials at Yuma, and the range reclamation work near Tucson. The line of sheep breeding entered upon two years ago by Mr. Wilson at the Station farm has resulted thus far in a rapidly increasing number of crosses which are now available for careful observation with reference to ideal combinations of qualities desired in range and valley types of sheep. The experiments in date culture (cooperative U. S. D. A.) have made satisfactory progress during the year, as detailed below; as have likewise cooperative grazing range investigations. The cultural work at Yuma has continued to demonstrate the remarkable productiveness of the fertile, alluvial soils of the Colorado Valley.

Detailed statements relating to the activities mentioned above, made by those directly concerned, are to be found on succeeding pages.

DATE CULTURE.

The date orchards, in charge of Mr. Simmons at Tempe and of Mr. Crane at Yuma, have made their usual steady growth and have produced a considerable, though not a maximum, crop of fruit in about 38 varieties. Some of these varieties are of no value to the region, due in some instances to inferior quality, in others to failure to ripen. Some varieties are valuable as fresh fruit only, being insufficiently sweet to keep when packed. Still others, a limited number, seem to satisfy all the requirements—earliness, palatability, and keeping qualities—of successful date culture in the region. Among these, it is interesting to note, are certain seedling trees of great promise, grown and brought to fruition in the orchard. There is little doubt that ulitmately the region will develop many of its own best varieties of dates, as has often been the case with other fruits in newly settled countries.

ENEMIES OF DATE CULTURE.

The gasoline-torch method for the extermination of date-palm scales continues to be effective and successful and is now believed to have solved the problem of control of these pests, particularly of the more dangerous *Parlatoria blanchardi*. The method is now reinforced by the Territorial law (Par. 2, Sec. II, Chapter 30, Laws of 1907) authorizing the inspection of date palms growing in or imported to the Territory and providing for their treatment or destruction in the event that they are found infested with scale or other dangerous insect pests.

The plague of rats which overran the Tempe orchard last year was fortunately not repeated; but the unending war with pocket gophers and, during the fruiting season, with birds, flies, beetles, and weevils still continues.

Following are the usual detailed statements of the condition of the orchards in September, 1907:

TEMPE DATE ORCHARD.

Importations.			Condition Sept. 18, 1907.				
Date received.	No. of varieties.	No. of trees.	Varieties living.	Trees living.	Offshoots growing.	Trees in bloom.	Trees dead.
Aug. 1, 1899.....	5	6					6
July 17, 1900.....	24	405	19	266*	2047	105	139
May 20, 1901.....	5	18	3	6†	62		12
Oct. 21, 1901.....	6	35	5	21	118	2	14
June 11–12, 1902....	46	212	28	57	200	5	155
May 24, 1904.....	39	41	27	27	83	13	14
July 12, 1904.....	13	13	13	13	16	2	
Aug. 8, 1904.....	4	7	3	5	13		2
Nov. 14, 1904.....	5	52	1	1	1		51
May 15, 1905.....	54	126	36	59	71	4	67
May 24, 1905.....	5	21	5	17	9	1	4
June 24, 1905.....	6	13	4	7	2		6
July 2, 1906.....	1	2	1	1			1
July 13, 1907.....	1	4					4
Aug. 8, 1907.....	3	12	3	12‡			
Totals	217	967	148	492	2622	132	475
Less 11 repeated			11				
			137				

* Including 11 trees of this importation growing at Station farm.
† Including 1 tree of this importation growing at Station farm
‡ Including 1 tree of this importation planted at Station farm.

Home-grown trees from various sources.			Sept. 18, 1907.				
Description.	Date rec'd.	Number.	Trees living.	Offshoots growing.	Trees in bloom. Male.	Trees in bloom. Female.	Trees dead.
Offshoots from W. Pickrell's male seedling	May 24, 1899	16	0				16
Three-year-old seedlings from Chas. Purdy, Alhambra.	Apr. 30, 1900	100	47	357		2	53
Offshoots from seedling male, University, Tucson	June 15, 1902	4	0				4
Miscellaneous two-year-old seedlings, University, Tucson	Apr. 17-18, 1906	124	5				119
Offshoots from Empress Eugenie, by M. E. Woods, Casa Grande	June 28, 1906	1	0				1
Offshoot from Timdjouert, Tempe orchard	June 4, 1906	1	1				
Itima from Station farm	July, 1907	1	0				1

YUMA DATE ORCHARD.

Importations.			Condition Sept. 24, 1907.			
Date received.	No. of varieties.	No. of trees.	Varieties living.	Trees living.	Trees in bloom.	Trees dead.
May 12, 1905	46	95	33	59	7	36
May 20, 1905	5	19	5	17		2
June 22, 1905	6	38	3	29	1	9
July 3, 1906	1	2	1	1		1
Total importations	58	154	42	106	8	48
Rhars from Tempe D. O. May 8, 1906	1	15	1	5		10
Assorted suckers from Tempe D. O. May 29, 1907	9	21	4	12		9
Total domestic	10	36	5	17		19
Total from all sources	68	190	47	123	8	67

Although over 200 suckers in the Tempe orchard were destroyed by the treatment of infested trees in 1906–7 for date-palm scale insects, the net increase in suckers during the year was about 650, showing a total increase of about 850 offshoots for the year. The second distribution of 268 suckers on behalf of the U. S. Dept. of Agriculture and of the Arizona Experiment Station was made during the spring and early summer to points in Arizona, California, and Texas. The fruit crop was small, this being the alternate year, although a larger number of varieties were in bearing than ever before.

The small palms in the Yuma orchard, the oldest of them only two years of age, did not bloom or bear except in a very few precocious instances.

THE YUMA GARDEN.

Continuing with crop cultures in the Colorado Valley near Yuma, even better success has attended the work of the second year on our demonstration area in this pioneering location. The best returns were received from cantaloupes, White Bermuda onions, tomatoes, and sweet potatoes, about three acres in these crops affording gross returns of over fourteen hundred dollars. The following tabular statement shows areas cultivated and gross and net returns from various crops tested:

Crop.	Acreage.	Marketable crop	Gross receipts.	Cash expenditures.	Net cash returns.	Days labor		
						Men.	Women and boys.	Team.
White Bermuda onions	1.20	23950 lb.	$ 605.73	$ 44.28	$ 561.45	87	9	10
Rocky ford cantaloupes	1.00	1600 doz.	517.71	98.79	418.92	100	12	22
Tomatoes	.52	5200 lb.	173 40	47.47	125.93	48	22	7
Sweet potatoes	.49	6380 lb.	154.99	10.85	144.14	53	..	8
Alfalfa	1.50	13½ tons*	..	20 35	....	22	..	7
Potatoes	.25	790 lb.	31.60	3.75	27.15	14	..	4
Watermelons	.50	. . .	. . .	.70		3	..	1
Totals	5.46	.....	$1483.43	$226.19	$1257.24 **	327	43	59

*Value $100.00, fed to team. **Deducting cost of alfalfa.

Such results from ground but two years under cultivation, in a region whose resources are as yet largely untried, indicate high intensive development in the not very distant future. To the Colorado Valley with its all-winter growing season, its productive soil, its abundant water supply, and its great variety of products, the populous mining towns of Arizona will in time to come naturally look for a large part of their food supply.

Following the demonstration acre of Rockyford cantaloupes mentioned above, Yuma Valley farmers have organized an association for the purpose of growing and marketing their products. About 300 acres have been pledged to cantaloupes for the season of 1908, and satisfactory arrangements completed with an Eastern firm to handle the crop.

PLANS AND PERSONNEL.

Following the departure of Professor Clark in May, the work in agriculture and horticulture has been divided into its constituent parts in order to permit of greater specialization along cultural lines. Dr. J. Eliot Coit of Cornell has undertaken investigations in horticulture, and Professor R. W. Clothier of the University of Florida, with duties for the present mainly along instructional lines, has been appointed Professor of Agriculture in the University.

Mr. Free has gone to the Bureau of Soils at Washington, and has been succeeded as assistant chemist of the Station by Dr. W. H. Ross of the University of Chicago.

These changes have, fortunately, been made with little loss of time to the work concerned, which has proceeded with very little interruption along well-planned lines.

EDUCATIONAL.

Farmers' institutes in Graham County towns, and lectures before academy classes in Thatcher, were continued as usual by Professors Wilson, Thornber, and Forbes. Twenty-three institutes were held, with lectures upon subjects relating to local agriculture, the total attendance being about six hundred. During February lectures were delivered on session days to the academy students at Thatcher, fourteen such lectures being delivered to an average attendance of about sixty.

The friendly reception of this work in this locality has encouraged plans for its extension next season with short-course work of several weeks duration at Thatcher, which has proved a convenient point from which to conduct these operations.

PUBLICATIONS.

Bulletins and reports for the year are as follows:

Bulletin 53, Sept. 20, 1906. Irrigating Sediments and their Effects upon Crops.—By R. H. Forbes.

Bulletin 54, Nov. 26, 1906. Timely Hints for Farmers, collected, edited, and illustrated.—By the Station Staff.

Seventeenth Annual Report, Dec. 30, 1906.—By the Station Staff.

Timely Hints for Farmers:

No. 60, July 30, 1906. Honey Vinegar.—By A. E. Vinson.

No. 61, Dec. 1, 1906. Disk-harrowing Alfalfa.—By R. H. Forbes.

No. 62, Jan. 1, 1907. Suggestions for Arbor Day Planting.—By J. J. Thornber.

No. 63, Jan. 15, 1907. A Lesson in Intensive Farming.—By R. H. Forbes.

No. 64, Feb. 15, 1907. Suggestions for the Control of the Codling Moth.—By J. J. Thornber.

No. 65, May 15, 1907. Contagious Abortion in Cattle.—By F. W. Wilson.

In addition to the regular Station publications listed above popular and technical articles upon subjects engaging the attention of members of the Staff have appeared as follows:

The Function of Invertase in the Formation of Cane and Invert Sugar Dates.—By A. E. Vinson, in the Botanical Gazette, 43:393–407, June, 1907.

Some Observations on the Date.—By A. E. Vinson, in the Plant World, 10:259–262, November, 1907.

The Toumey Cactus Garden.—By J. J. Thornber in the Plant World, 9:273–277, December, 1906.

Alfilaria in Arizona.—By J. J. Thornber in the Plant World, 10:205-208, September, 1907.

THE LIBRARY.

After repeated revisions of the material the collection of Experiment Station and Department of Agriculture publications has finally been brought to a state of very satisfactory comple-

tion. One practically complete set of these publications is in process of binding, while two more are available in the library for reference.

It is a matter of regret that this library as well as the scientific laboratories and collections still continue to be housed in the very inflammable old University Main Building. Fireproof vaults or buildings are increasingly needed with the growing values at stake.

FINANCIAL.

For the year ending June 30, 1907, receipts from the Federal Government were twenty-two thousand dollars, with various sums from other sources, as follows:

From the Treasurer of the United States, Hatch Fund	$15000.00
From the Treasurer of the United States, Adams Fund	7000.00
From the University Territorial Fund	301.76
Farm sales, Station farm	459.59
Produce, Tempe date orchard	132.25
Produce, Yuma date orchard	1211.03
Miscellaneous sales, refunds, fees, etc.	587.00
Experiment Station Bond Fund	430.42
Publications, Laws of 1905, No. 59, Sec. 1, Par. 4	504.79
Date Palms, Laws of 1907	347.47
Southern Pacific appropriation for irrigation investigations	2500.00
Balance from 1905–6	793.50
Overdraft carried to 1907–8	203.99
Total	$29471.80

The following detailed statement of expenditures, by departments of work, by schedules, and by funds, is complete and self-explanatory.

R. H. FORBES,
Director.

EXPENDITURES BY SCHEDULES AND DEPARTMENTS FOR THE YEAR ENDING JUNE 30, 1907.

		Administration.	Agriculture and Horticulture.	Animal Husbandry.	General Farm Expenses.	Botany.	Chemistry.	Entomology and Meteorology.	Date Orchards.		Miscellaneous.	Total.	
									Tempe.	Yuma.			
Hatch Fund, $15,000.	Salaries	2090.52	1775.49	1055.13	.....	1376.66	333.46	86.55	597.00	.....	.....	7314.81	
	Labor	5.50	1044.12	65.00	18.50	631.08	159.90	66.76	166.15	.....	.....	2157.01	
	Publications	154.38	30.36	85.39	24.16	44.31	65.29	44.21	30.91	.....	.....	479.01	
	Postage and stationery	395.89	14.45	56.53	52.45	1.75	3.70	3.56	40.50	.....	.....	568.83	
	Freight and express	114.09	9.87	67.02	1.22	30.74	176.49	296.08	11.69	.....	.....	707.20	
	Heat, light and water	25.10	.....	.....	.....	6.00	59.25	18.85	3.57	.....	.....	112.77	
	Chemical supplies	5.00	9.70	23.05	.....	63.81	121.03	5.00	8.30	.....	.....	235.89	
	Seeds, plants and sundries	1.15	100.81	44.26	36.83	26.54	2.85	12.80	77.59	.....	.....	302.83	
	Fertilizers	.....	.....	.....	200.77	.....	.....	.....	7.85	.....	.....	208.62	
	Feeding stuffs	.....	40.59	191.78	43.70	.....	.....	4.00	9.05	.....	.....	289.12	
	Library	.....	5.00	1.00	.....	.....	.....	.....	.....	.....	.....	6.00	
	Tools, implem'ts and mch'y	39.30	135.85	315.24	96.18	25.74	12.14	11.25	59.55	.....	.....	695.25	
	Furniture and fixtures	316.81	.35	18.70	31.75	169.55	.25	.25	.....	.....	.....	537.66	
	Scientific apparatus	2.20	.....	8.95	1.00	37.60	51.42	15.60	.....	.....	.....	116.77	
	Live stock	2.50	1.50	170.00	125.00	.....	.....	10.00	4.50	.....	.....	313.50	
	Traveling expenses	215.00	36.70	18.15	10.60	53.50	39.85	46.55	56.45	.....	.....	476.80	
	Buildings and repairs	44.50	21.47	78.09	234.52	57.55	11.43	.....	30.37	.....	.....	477.93	15000 00
Sales fund.	Labor	.....	.....	1038.34	.....	49.68	.....	.....	494.25	901.81	.....	2484.08	
	Sundry supplies	.....	.....	.....	.....	.....	.....	.....	.....	545.15	.....	.....	
	Publications	.....	.....	.....	.....	.....	.....	.....	.....	65.81	.....	610.96	
	Contingent	79.10	.....	14.00	.....	.....	.....	.....	.....	.....	.....	93.10	3188.14
Bond fund.											Inst. W'k		
	Salaries	.....	.....	.....	.....	.....	.....	.....	.....	.....	233.32	.....	
	Traveling	.....	.....	.....	.....	.....	.....	.....	.....	.....	197.10	430.42	430.42
Laws '05.	Publications	.....	79.49	.....	.....	50.00	332.90	42.40	.....	.....	.....	504.79	504.79
Laws '07 Date-palms	Labor	.....	.....	.....	.....	.....	.....	.....	.....	294.05	.....	.....	
	Sundry supplies	.....	.....	.....	.....	.....	.....	.....	.....	53.42	.....	347.47	347.47
Univ. Ter. fund.	Salaries	168.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
	Labor	.....	.....	.....	.....	.....	.....	.....	.....	91.85	.....	.....	
	Sundry supplies	.....	.....	.....	.....	.....	.....	.....	.....	41.31	.....	301.76	301.76
	Total cost of departments	3659.64	3305.75	3250.63	876 68	2624.51	1369.96	663.86	1597.73	1993.40	430.42		19772.58

EXPENDITURES BY SCHEDULES AND DEPARTMENTS FOR THE YEAR ENDING JUNE 30, 1907.—CONTINUED.

		Sheep Breeding.	*Botanical Studies.*	*Plant Diseases.*	*Toxicity of Copper.*	*Date Ripening.*	*Underflow Investigations.*		
Adams Fund, $7,000.00.	Salaries	137.32	600.00	699.96	1131.05	1777.73	1817.65	6163.71	
	Labor	.....	21.50	.....	.....	.....	143.25	164.75	
	Freight and express	2.99	7.45	12.05	4.76	65	70.09	97.99	
	Heat, light, water and power	.....	.....	.....	.....	.....	2.60	2.60	
	Chemical supplies	.....	.....	1.85	1.70	22.68	9.40	35.63	
	Seeds, plants and sundries	.....	.....	2.20	.....	.....	62.71	64.91	
	Library	.....	.....	13.04	.....	.....	.....	13.04	
	Tools, implements and machinery	.....	.....	.....	.....	.....	268.40	268.40	
	Scientific apparatus	.....	.....	21.01	.....	20.50	119.86	161.37	
	Traveling	.....	.....	.....	.....	.....	27.60	27.60	7000.00
S. P. and sales funds $2699.22.	Salaries	.....	.....	.....	.....	.....	1219.32	.....	
	Payroll	.....	.....	.....	.....	.....	416.34	.....	
	Boarding	.....	.....	.....	.....	.....	144.00	.....	
	Travel	.....	.....	.....	.....	.....	69.25	.....	
	Machinery, material	.....	.....	.....	.....	.....	835.71	.....	
	Machinery, operation	.....	.....	.....	.....	.....	14.60	.....	2699.22
	Totals	140.31	628.95	750.11	1137.51	1821.56	5220.78	.....	9699.22

AGRICULTURE AND HORTICULTURE.

Prior to the departure of the agriculturist and horticulturist in May, various papers were prepared by him on certain of the experimental undertakings of the preceding two years, some of which are forthcoming as publications of the Station.

NURSE CROPS FOR ALFALFA.

Observations on Nurse Crops for Alfalfa, published Aug. 25, 1907, as Timely Hint No. 66, calls attention to the deleterious effects upon young alfalfa plants of wheat, oats, and rye used as nurse crops. It is pointed out that usually the loss in yield of alfalfa due to a nurse crop probably more than offsets the extra return from the nurse crop itself.

BROAD BEANS AND HORSE BEANS.

Broad beans and horse beans as grown on the Station farm appear on final judgment to be of doubtful value in Arizona agriculture. Broad beans in particular are susceptible to frost, and both broad and horse beans perish on the advent of hot weather in May or early June. The growing season is therefore too short for satisfactory results with this crop. There are wide variations, however, in the endurance of frost by these beans, both among individuals and varieties. Among the broad beans the least injured were Sutton's Green Giant, a tall variety, and Aquadulce, a dwarf but very bushy and vigorous variety. The Avas, or Mexican varieties, are acclimated to conditions like our own and were among the most frost-resistant sorts. The horse beans from Algeria are not nearly so hardy and are unable to withstand winter temperatures at the Station farm.

While these cultures may not be considered economically successful, they are not wholly without promise as there is indication that selection and acclimatization might ultimately result in the development of sorts sufficiently resistant to winter frosts in the mildest Southwestern localities.

The original supply of broad beans used in these tests came from England, and of horse beans from Algeria, both being received from the U. S. Department of Agriculture. The Avas were obtained directly from Sonora and Lower California.

PROTECTION OF PLANTS FROM EXTREMES OF CLIMATE.

The protection of plants from extremes of Arizona climate is considered in connection with commonly observed injuries due to such causes as excessive heat or cold, desiccation, and light intensity. Various devices are available to this end. Sheltering cultures may often be employed for the protection of less hardy plants against winter frosts and the intense heat, evaporation, and light of summer. Cotton, sorghum, field corn, Sesbania, and vines have thus been used to successfully protect such perishable plants as raspberries, currants, and gooseberries. By pruning trees and vines to compact forms self shelter may be economically secured. Artificial covers of lath or cloth, or tree-trunk protectors, effect the same purpose, though at serious expense.

Cultural methods, also, are sometimes effective. For instance, by planting on the south slopes of ridges in winter temperatures may be materially increased, while an opposite effect may be secured on north slopes in summer. Likewise, irrigating water may be used for the control of soil temperatures both in winter and in summer.

In brief, an economic degree of control of factors influencing growth is possible through the employment of shelters and rational methods of culture.

SELECTION OF SEEDS BY SPECIFIC GRAVITY.

Selection of seeds by specific gravity has yielded suggestive results from both scientific and economic points of view. By using sets of neutral liquids of different densities, the seeds studied were separated into series of fractions gradually increasing in specific gravity. In each series thus obtained optimum or most favorable specific gravities were usually observed with reference to certain desirable vegetative characters, such as per-

centage of germination of seeds, earliness, quality, form and yield of fruit, weight of roots, and characters of stems and leaves.

Specific gravity consequently affords a means of selecting really good seed with reference to a particular objective. This method of selecting seed is therefore of manifest value to market gardeners and plant breeders, and in certain instances may even be found practicable for the ordinary farmer.

It is hoped that this work will soon appear as a Station bulletin.

V. A. CLARK,
Agriculturist and Horticulturist.

ANIMAL HUSBANDRY.

SHEEP BREEDING.

In the work in sheep breeding two main objects are borne in mind: one is to develop a suitable type of sheep for the range; the other a type of sheep for the irrigated valleys of the region.

Three things are essential to profitable types of range animals: the ability to grow a profitable wool clip, to produce good mutton lambs, and to stand herding together in large numbers.

Four things are essential to profitable types of valley animals: the ability to grow a profitable clip of wool, to produce good mutton lambs, to breed with regularity at any season of the year, and to withstand the extreme heat of summer.

Native ewes that have endured the extremes of climate, feed, and other range conditions have been chosen for the foundation flock. These ewes, so far, seem to give the progeny better constitution and herding qualities.

For use with this hardy foundation stock, ideal types of rams have been obtained with which it is hoped to secure the desired combinations of qualities for both range and valley. We now have ideal types of Tunis, Oxford, Shropshire, and Rambouillet rams for this purpose, and breeding operations are in progress on the general plan outlined.

Of the Tunis-Native cross we now have two rams, six ewes, and seven wethers. These cross-bred lambs are vigorous, active, and early maturing. The general conformation is on the order of the Tunis with an improved quality of wool over that of the Tunis. The large tail of the Tunis is lacking in the cross-breds. At birth the lambs are of various colors, brown or tawny predominating. Later the color fades to a brownish white.

The Tunis are very prolific, there being several sets of twins and one set of triplets. Very little difference, if any, can be noted in the size and vigor of twins from that of the single lambs.

This is probably due in a great measure to our peculiar climate and abundance of green feed the year round.

Manifesting their appreciation of the work entered upon, several interested sheep-breeders have donated a considerable number of high grade animals to the Station.

EFFECTS OF OVER-PASTURING.

With a view to determining the effects of close grazing upon alfalfa, two lands, A and B, divided into four plots each, were located in the middle of a two-acre plot of alfalfa five years old. These plots were numbered 1, 2, 3, and 4 in each land, being 30 x 30 ft., 30 x 120 ft., 30 x 60 ft., and 30 x 60 ft., respectively. The plots in Land A were subjected to various treatments, the plots in Land B, of equal size alongside, serving as checks. On plot 1 in Land A the alfalfa was cut even with the ground with a pair of sheep shears each time it reached a height of four to five inches. The alfalfa in plot 2 was cut for hay in the ordinary manner. The alfalfa in plot 3 was cut with a pair of shears after the manner of sheep grazing it off by pasturing. Plot 4 was actually pastured by two two-year-old wethers. The experiment was begun April 1st. At the end of the season the effect of these various treatments was determined by counting the number of living stools of alfalfa remaining in plots 1, 2, 3. and 4 and comparing them with each other and with the check plots alongside. The following table shows these results reduced for purposes of comparison to terms of plot 1, 30 x 30 ft. in area.

NUMBER OF STOOLS OF ALFALFA LIVING AT END OF EXPERIMENT.

Plot No.	For comparison, stated by areas of 30 ft. x 30 ft.		
	Land A. Various treatments.		Land B. Check.
1	Cut when 4-5 inches high.....	995	2548
2	Cut with mower for hay.....	2046	2188
3	Cut with shears as sheep graze.....	1386	1965
4	Pastured with sheep..	915	1800

It will be noted that in plot 1, cut when 4–5 inches high, the loss of alfalfa was 61 per cent. Plot 2 agrees quite closely with check, showing the stands of alfalfa to have been fairly uniform. In plot 3, cut with shears after the manner of sheep grazing, the loss of alfalfa plants was 30 per cent. In plot 4, actually grazed

by sheep, the loss was 49 per cent. The losses noted in plots 1, 3, and 4 are evidently due to the continual cutting back of the alfalfa plants by shears and sheep; so that with a scant covering upon the ground the sun and wind not only dry and crack the soil but injure the constantly exposed stools, many of which ultimately perish.

On farms where sheep are kept, this loss by heavy pasturage can be avoided in various ways. For instance, alfalfa fields may be harvested in succession, pasturing each field after cutting with a flock of sheep for a few days, thereby cleaning up waste hay and objectionable weeds. But the pasturing of alfalfa by sheep just after the field is wet has the effect of tightening the land to a serious extent, as the hoofs of sheep and their close herding habits tend to puddle wet land, with consequent difficulty in irrigation.

SHRINKAGE OF HAY IN THE STACK.

In 1906, the alfalfa from a selected field of two acres was carefully cut, cured, and placed in one stack. The dates of cutting, irrigation, and weight of new mown hay were as follows:

No. of cutting.	Dates of cutting.	Irrigation.	Pounds of new mown hay.
1	Apr. 19	Apr. 22	4655
2	May 28	May 30	5285
3	June 25	June 30	5535
4	July 21	July 27	3810
5	Aug. 28	Sept. 25	4685
6	Nov. 9		1560
Total			25530

The hay remained in the stack until Feb. 11, 1907, when it was carefully weighed: at this time there was 22,705 pounds of hay, a loss due to shrinkage of 2,825 pounds, or 11 per cent.

The following season the third crop of hay from the entire farm was cut and the stack completed about July 20. This stack contained 23 tons and 1,796 pounds. The stack was sold December 14th and at that time contained 17 tons of first-class hay, and 2,825 pounds of poor hay, or a total of 18 tons and 825 pounds, a shrinkage of 5 tons and 971 pounds, or 23 per cent.

These results are of interest in connection with the marketing of alfalfa hay, as they bear upon the question whether it is advisable to bale and sell hay direct from the field, receiving a lower price per ton, or whether it is best to hold the crop until later for an increased price with a certain loss by shrinkage.

MISCELLANEOUS.

Contagious abortion in cattle. A Timely Hint on Contagious Abortion in Cattle was published late in the year, which should be of special interest to the dairy farmer, as this disease is becoming quite prevalent throughout the Territory. This publication deals particularly with methods for holding the disease in check. We were successful in cleaning up contagious abortion on the Station farm by strict sanitary methods, as explained. There is need of legislation for the purpose of holding this disease within bounds. Numerous instances have been brought to the writer's notice within the past year in which dairymen have sold affected animals to unwary purchasers. It is hardly necessary to state that this practice is causing the disease to spread rapidly from one herd to another.

Fair work. A number of animals were fitted at the Station farm for exhibition at the Second Annual Territorial Fair. The following prizes were secured: First prize for best farm team, second prize for two animals produce of one mare, first prize for grade fat heifer, first prize on Poland China sow one year old and over, first prize on Poland China sow and six pigs, first and second prizes on Rambouillet ewe two years old or over, first prize on Shropshire ram under one year and first and second prizes on grade wether.

F. W. WILSON,
Animal Husbandman.

BOTANY.

RANGE CONDITIONS.

As concerns temperature and amount and distribution of its annual rainfall, the year ending June 30, 1907, was the exact counterpart of the previous one. The total precipitation on the small range reserve was 13.02 inches, of which amount 4.27 inches fell during the summer period, July to September inclusive, and 7.20 inches during the winter rainy period, November to April. There was considerable growth of the summer annual species on the mesas, chiefly in the swales and other similar depressions, during July and August. This, however, dried up early in September, which month was notably dry. Ot the winter rains 6.55 inches fell in December and January, which months on account of the prevailing cooler temperatures are least favorable for plant growth, and only .65 inches during the more favorable growing months, February to April. On account of the dry spring the winter growth was cut very short. The excellent stands of Indian wheat and alfilaria which were prominent features in the landscape during January and February grew two to three, and five to six inches high, respectively, whereas with a more timely distribution of the same rainfall the growth would have been several times as heavy. There appeared to be no more annual growth in the large range reserve nor in the foothills of Santa Rita and Santa Catalina Mountains than about Tucson and in the small range reserve.

Of the fifteen varieties of seeds sown June 28, 1906, on land occasionally flooded by Woodward's contour dam, only one, alfilaria, made sufficient growth to warrant mention. Considering the season, good results were secured with this plant, the best growth obtaining where the seed was cultivated in. Mr. W. B. McCleary of Helvetia also secured an excellent growth, though on a small scale, from seed sown in his pasture. There appears to be little question, therefore, concerning the practicability of introducing this plant by means of seed.

The experiments in planting cacti have been continued. A half-acre or less of each of the following varieties were planted in March, 1907: *Opuntia arbuscula, O. engelmanni, O. phaeacantha, O. fulgida, O. mamillata, O. spinosior*. The cuttings used for this year were for the most part double the size of those planted in past years, and generally of older growth. They were also set deeper in the ground than heretofore. Those of the prickly pears and *Opuntia arbuscula* were exposed to the drying effects of the weather for about two weeks before being planted, while the cuttings of the various species of chollas, on account of their fragile character, were cut and set immediately. Altogether 2,500 cuttings were planted. The method of planting was the same as that used last year. The cuttings were set in a deeply plowed furrow against the side next to the ridge and covered to the proper depth with a second furrow. Very few of the plants were molested by rats,rabbits,or other range rodents, which is quite the opposite of last year's experience. Growth appeared to begin soon after planting, and continued throughout the summer, which was notably favorable. Many of the plants grew from twelve to eighteen inches in height and produced a good number of lobes, large and small. At this time (December 31, 1907) these plants average at least twice the size of those of corresponding plots that were set one year earlier. It is interesting to note that this encouraging growth obtained in the instance of every species tested. This experiment will be duplicated the coming year to determine further the relation of growth between deep and shallow planting, and of cuttings made from old and from new wood.

SALTBUSH WORK.

For experiments with saltbushes and other forage plants, the Experiment Station last February leased a plat of ground in the vicinity of Ft. Lowell, containing approximately two and one-third acres, for a period of three years with the privilege of renewal for three additional years. This area was immediately cleared of brush and enclosed with a substantial four-wire fence. The land may be irrigated conveniently should occasion require, and since there is a variation from almost none

to a considerable quantity of alkali in the soil, it is especially adapted to work with saltbushes. In March one-half of this plat of ground was set with saltbush plants which had been grown in pots during the previous fall and winter in order to further the experiment. Since the winter rains stopped early in February, these plants were occasionally watered by hand until it was thought they were sufficiently well-rooted to need no further attention The following varieties were planted: *Atriplex semibaccata, A lentiformis, A. polycarpa, A. canescens, A. confertifolia, A. halimoides, A. nuttallii, Eurotia lanata, Rhagodia linearis, R spinescens* Many of these plants died during the hot dry months of May and June; these were reset with other plants in July with the beginning of the summer rains. The results thus far have been entirely unsatisfactory. From forty to sixty per cent of the plants have died, there being little difference in this respect between those set during the spring and the summer months. Of those that lived, with the exception of a few of *Atriplex semibaccata*, very poor progress was made.

DESTRUCTION OF RANGE WEEDS.

The rapid spread of the rayless golden rod, *Isocoma hartwegi*, and similar weeds over the ranges led the writer to consider economical means of destroying them On June 28, 1906, a considerable patch of the rayless golden rod lying along one of the abandoned roads within the fenced portion of the small range reserve tract was burned off, due care being exercised to keep the fire within bounds. All the plants in the area burned over, even those only partly charred, were killed outright, including such other shrubs as the catclaw, creosote bush, Brigham's tea, mesquite, and *Zizyphus* This may prove an easy means of destroying well-defined patches of such worthless range weeds as the above, when growing in the open. About fifty per cent of the plants of another patch of rayless golden rod which were cut a year later, two inches above ground, were destroyed. When, however, the plants were cut somewhat below the surface of the ground all were killed It goes without saying that the latter method is much more expensive than burning off.

ORNAMENTAL PLANTING.

Timely Hint No. 62, "Suggestions for Arbor Day Planting," was issued January 1, 1907, It is especially valuable for those parts of Arizona below altitudes of three thousand feet. It includes a list of palms and evergreens and deciduous trees that are commonly grown successfully. The honey locust, mesquite, bagote, palo verde, screw bean, ironwood, and soapberry or wild China berry are recommended as extremely drouth-resistant species. Among the newer or less known varieties of evergreen ornamentals that are recommended for planting, where proper care may be given them, are the cedar of Lebanon, Indian cedar, *Cedrus atlantica*, Monterey cypress, Chinese arbor vitæ, *Eucalyptus rudis*, and *E. polyanthema*. A short paragraph containing suggestions for the planting and subsequent care of trees in this climate, based on the writer's experience, was included.

THE CODLING MOTH.

In February the writer prepared a Timely Hint dealing with the codling moth in Arizona. Quite recently this enemy of the apple grower has appeared in abundance in several of our best agricultural localities, notably the upper Gila Valley, upper Verde Valley, St. Johns, and to a limited extent along Oak Creek. The life history of this insect, including descriptions of its various stages and the importance of timely spraying, was discussed. Spraying with some arsenical poison, as arsenite of lime with soda, was recommended. The cost of materials for spraying an orchard of five hundred average-size trees with the above spray mixture once, was estimated not to exceed one dollar and fifty cents.

J. J. THORNBER,
Botanist.

VEGETABLE PHYSIOLOGY AND PATHOLOGY.

The work in plant physiology and pathology was separately organized under the provisions of the Adams Act at the commencement of the present year, and the duties connected therewith assumed by the writer Jan. 1, 1907. A liberal equipment of apparatus has been provided so that laboratory facilities for investigation are very adequate.

A word on natural conditions will help to indicate the nature of physiological and pathological problems peculiar to the region. Considering the climate alone, the most important features influencing plant life, at least in southern Arizona, are the extreme heat, low humidity, and intense illumination of the summer, and the occasional frosts of the winter. Apart from soil conditions, or the possibilities of water supply, it is these features that determine what plants can grow here, for plants whose optimum or minimum for any one factor lies beyond these limitations would be unable to exist. But a plant may grow in conditions that go beyond the optimum or minimum for some particular function, so that growth as a whole may be abnormal, the plant growing well in some respects but poorly in others, or some structure or part may be omitted. So it is here, and we find during the hot weather many plants will grow well enough but run all to vegetative structure, refusing to "set" fruit. Tomatoes, for example, produce luxuriant foliage but only a few varieties will form good fruit. Most of the small fruits seem to be the same. Corn grows well but also produces little grain. Irish potatoes, though producing luxuriant vines, occasionally do not set tubers. In this case it is undoubtedly the influence of high temperature, but with the other plants it is not clear what part the intense illumination may play.

The winter, too, as suggested, places serious difficulties in the way of successful cultivation of many plants, for apart from frost-resisting sorts many plants otherwise suitable are stimulated by the warm winter weather into premature leaf and

flower, and then are caught by the next frost and their usefulness for that season is ended.

Of the physiological problems arising out of these conditions brief mention will be made of those upon which work is now in progress. In the culture of the Irish potato the custom is to grow it during the period between the last frosts of winter and the hot weather of summer. This period is usually too short to mature any but the earliest varieties, and a method is being developed which will shorten materially the time necessary for tuber formation. Some crops, such as tomatoes, would grow during the late winter weather, and it is of great importance to bring these on the market as early as possible; but they must be held back until all danger of severe frost is over. Methods of treatment and culture that will bring the tomato into fruit much earlier are being worked upon, and the results thus far are very encouraging.

The pathological phase of this work also presents very important problems. The extreme aridity, coupled with the high temperature, and perhaps also the great insolation, reduces to a minimum those plant diseases which attack the aerial parts of plants. But on the other hand the high temperature of the soil provides an excellent incubator for the growth of fungi, so that our most common and destructive diseases are from this source. Perhaps the most common is the root-rot disease attacking alfalfa, tomatoes, melons, cantaloupes, and other crop plants. This fungus, a species of *Fusarium*, seems to be quite general in the soil in this region, and on account of its prevalence and destructiveness a thorough investigation of its character and life history has been undertaken and is now in progress. As the fungus apparently may live on indefinitely in the soil it is one of the most difficult to successfully combat, for the ordinary methods of attack, such as treatment with substances poisonous to the fungus, are impossible here. As this fungus is of such wide occurrence and so difficult to get at, it seems most likely that the solution of the trouble will be reached by attacking it from the opposite direction; that is, by developing races of plants able to resist its ravages.

A disease recognized for the first time in this region is the black rot of the cabbage, which is causing great destruction in those fields where it occurs. A separate publication on this is being prepared.

During the year a number of unhealthy plants were sent in for identification which showed no trace of either fungus or bacterial disease. Notable cases were those of oranges, peaches, and tomatoes. The troubles were physiological in nature due to conditions quite unknown. Indeed, probably our most serious diseases are those of this kind. The fungus diseases, owing to our adverse climatic conditions, probably never will assume the importance they do in many other parts of the country, and remedial measures are constantly being ascertained. On the other hand little or nothing is known of the causes of these physiological troubles. They are very destructive, and are so local in their distribution that other institutions are not likely to investigate them.

W. B. MCCALLUM,
Associate in Vegetable Physiology and Pathology.

CHEMISTRY.

The efficiency of this department has been increaed greatly during the past year, not only by additional equipment, but by the accession of an assistant chemist. Thus the older members of the staff have been relieved of many routine analyses for the general public and the other departments, besides being very materially assisted in the great amount of analytical work relating to their own special problems The assistant chemist has been able also to carry on some lines of original research bearing upon the general work of the department. For the most part the subjects of the previous year have been followed and enlarged upon.

THE RELATION OF COPPER MINING DETRITUS TO AGRICULTURE.

The first section of this work, dealing with the effect on cultivated lands of sediments in irrigating waters, appeared in Bulletin No. 53 by R. H. Forbes and was discussed in the Seventeenth Annual Report. During the past year the second section of this work, which traces the copper from the mines through the irrigating water into the products of the soil, has been completed and will be published soon. In carrying out the analytical work connected with this E. E. Free perfected the technique of the determination of very minute quantities of copper by depositing the metal electrolytically on a small platinum spiral weighing about one-third of a gram, which could thus be weighed with extreme accuracy on a delicate assay balance. This method was presented by Mr. Free before the annual meeting of the Electro-chemical Society in New York City.

It was also necessary to determine accurately the solubility of basic copper carbonate, malachite, in water charged with carbon dioxide, and the influence of those compounds which occur in irrigating water upon this solubility. Some facts of considerable scientific importance as well as practical utility

were brought out by these determinations. They will be discussed by Mr. Free in a future paper. The third section of this work, dealing with the toxicity to crops of soluble copper compounds under the various qualifying conditions occurring in the soil, is being investigated as rapidly as the nature of the work will allow.

CHEMICAL COMPOSITION OF THE DATE-PALM FRUIT.

In the Seventeenth Annual Report mention was made of the fact that the varieties of dates could be divided into two general classes, invert sugar dates and cane sugar dates, but that all dates were decidedly cane sugar dates at some period of their growth. Certain varieties retained this cane sugar as such while others transformed it into invert sugar. Further investigation has shown this to depend upon the absence or presence of an enzyme known as invertase. The primary difference between the dates is thus one of enzymes and the relation of the sugar is only secondary. The relations between dextrose and levulose in the invert sugar date and the presence of large amounts of cane sugar at some period show conclusively that practically all the sugar of the date passes through the form of cane sugar. For other theoretical considerations we are forced to believe that this sugar must enter the fruit as maltose. These features, which must form the foundation of any rational and non-empirical method of artificial ripening and curing of dates, have been discussed at length by A. E. Vinson in a paper entitled "The Function of Invertase in the Formation of Cane and Invert Sugar Dates," published in *Botanical Gazette*, vol. 43, pp. 393–407, June, 1907. A limited number of reprints of this article, which is entirely technical in form, are in the hands of the Station and can be had by any one especially interested. It has been considered desirable to publish work of this nature, which will eventually form the foundation stones for a rational date culture, in a scientific journal rather than a Station bulletin. In that way greater usefulness and wider recognition is obtained among scientific workers, and the facts are more permanently recorded, since these journals are filed and always accessible in the leading scientific libraries.

The more recent work upon the date has been largely a study of the changes in the relation of the invertase, which may be taken as a representative enzyme, to the process of ripening. As noted in the paper previously mentioned, the invertase of the green date cannot be extracted by the usual solvents of enzymes, but when the fruit begins to ripen the enzyme becomes readily soluble. It has been shown conclusively that this is not due to the disappearance of the soluble tannin. The accepted theory for these cases of so-called endoenzymes is that the cell walls are impervious to them, but we find that this theory is not in keeping with the observed facts for the green date. It has been suggested, therefore, that in this case at least, the enzyme in some manner forms an insoluble compound with the protoplasm. Active insoluble compounds of invertase have been prepared in this laboratory. The theory of an insoluble form of the enzyme is equally applicable to most of those cases that have been explained by impermeability of the cell wall to the enzyme which is supposed to exist always in solution in the cell sap.

The study of the tannin relations has been very profitable, although they have not been investigated so exhaustively as have the invertase relations. Upon ripening, the astringency of the date disappears and the tannin is laid down as reddish-brown granules in certain giant cells near the surface of the fruit. If the pulp is stirred up with water these granules separate out rapidly, being specifically heavier than the other constituents, and can be separated thus in a nearly pure state by mechanical means. It is our intention to investigate these granules. Some progress has been made relative to the chemical mechanism of the disappearance of the astringency in fruits. It has been repeatedly observed that formaldehyde in the presence of a little acid forms insoluble condensation products with tannin, phenols and oxybenzoic acids. This was observed at this Station also about ten years ago in treating canaigre extracts with formaldehyde. Very recently these facts have been applied to explain the deposition of tannin in the cork layer of plants, the necessary formaldehyde being assumed to exist in the tissues, since its presence in the other parts of the plants has been demonstrated.

Working on these suggestions the writer treated Deglet Noors with formaldehyde and found the tannin to be rendered insoluble in a very short time. After this some of the other phenomena of ripening followed quickly. In all cases, however, the fine flavor of the fruit was destroyed; but when the conditions are better understood this difficulty may be avoided. Acetaldehyde was found to precipitate canaigre extract with the same facility as formaldehyde, and gave practically the same results in treating dates. It is not improbable that the explanation of the Japanese method of ripening persimmons by enclosing them tightly in empty *sake* barrels may be found in these facts. Small amounts of acetaldehyde or other aldehydes are probably present in such barrels.

The microscopic investigation of the tannin of the date has been undertaken by Professor F. E. Lloyd. His work has not progressed sufficiently to give any very definite results excepting that the tannin is generated in the giant cells where it is finally deposited. Other observations made by Professor Lloyd promise to bring out some new and interesting facts.

As usual the department has done considerable miscellaneous work, including a chemical hydrographic survey of the division line between the Santa Cruz and Rillito underflows.

A. E. VINSON,
Associate Chemist.

IRRIGATION INVESTIGATIONS.

The principal limitation upon the extension of agriculture in Arizona is the amount of water that can be developed for irrigation. Every surface stream has been appropriated for many years past and the scarcity of water has been felt more and more keenly. The unprecedented activity in the copper mining camps of the Territory and the rapid growth of population in the cities have created a phenomenal demand for agricultural products. This, in turn, has stimulated efforts to obtain water with which to convert the valley and mesa deserts into fields and orchards.

The two alternatives that are now left open for increasing the water supply are the storage of flood waters and the utilization of ground waters. The former requires capital because of the heavy outlay for dams and canals, while the latter requires a constant expenditure for operation. In either case more responsibility rests upon the irrigator to make both ends meet and to show a profit than when drawing surface water from a river In both cases the engineer's aid is valuable, and in no wise more so than in determining, in advance of the construction, the amount of water which can be profitably obtained.

Naturally, then, the first undertaking of this department has been the study of water resources.

THE UNDERFLOW OF RIVERS.

The rivers of Arizona have a remarkably high gradient. Many of them, flowing out from granitic mountains, carry in flood-times a freight of coarse siliceous sand which is distributed along the river courses in loose porous deposits. The recurrent floods, however, are soon spent and the rivers in normal condition are dry beds of sand. But while the floods last they have a very useful function, the filling of the sand beds with water. During the dry periods this stored water under the action of gravity percolates downstream through the river sands, constituting what is popularly termed the underflow.

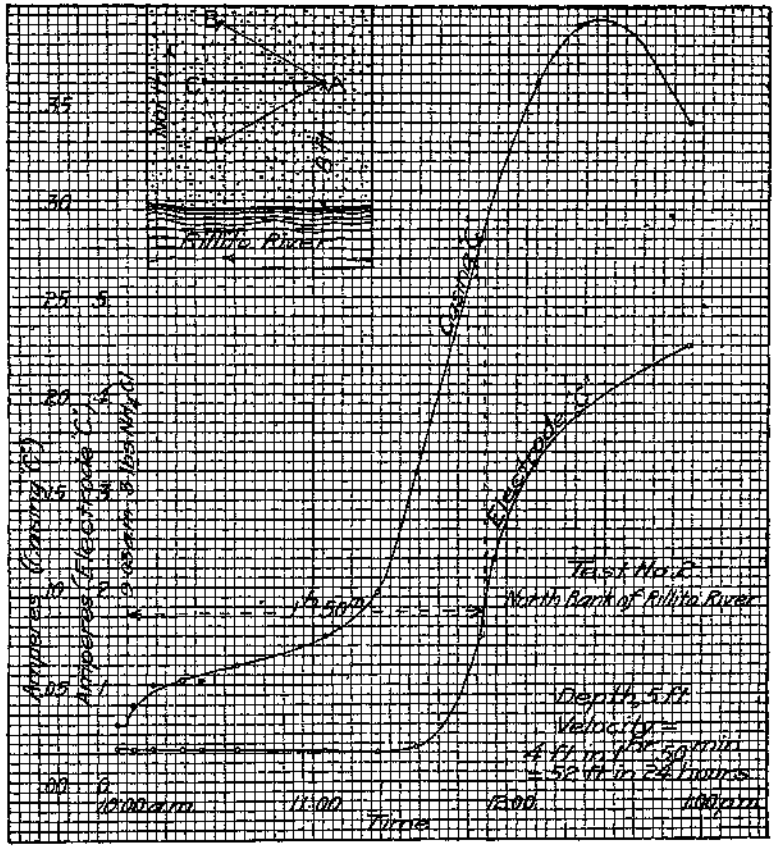
In some cases the underflow is also fed by a slow but broad and profound movement of water directly from the mountains to the valley trough. In other cases the underflow of a river is dissipated by the seepage in a direction away from the river.

The Rillito river, a few miles north of Tucson, receives a small inflow from its right bank, but loses much water by percolation southward from its left bank. The Pantano Wash, which in flood time is an impassable torrent, has no underflow. Water which escapes downward through its bed joins in the deep water movement which bears no relation whatever to the river course.

The Rillito, Santa Cruz, San Pedro, Sopori, Sonoita, and many other streams carry a true underflow parallel with the river course. To the ranchers along the banks of these streams the underflow must be what the surface water is to irrigators from streams of perennial flow.

The theorem of (comparatively) rapid underflow through the river sands has the unfavorable corollary that the position of the water table in these sands fluctuates through a wide range. This feature is quite fatal to the successful operation of gravity ditches because it always happens that when water is most needed for the land the water table is at the lowest ebb and the water supply is therefore at a minimum. There are, however, many places where bed rock, or lava flows, or partially consolidated gravels, or other "accident of nature" contracts the underflow and holds it near the suface. An example of this is seen on the Rillito at Tanque Verde, and again for a stretch of two miles near old Fort Lowell, where the underflow is sufficient to feed nine small gravity ditches.

At the Canoa ranch on the Santa Cruz an underflow ditch develops sufficient water to irrigate 200 acres. The Flowing Wells ditch on the outskirts of Tucson waters 700 acres in winter and 500 acres in summer. Allison Bros. ditch on the Santa Cruz develops underflow sufficient for 200 acres, and will be enlarged until 300 acres are under cultivation. The fields of the upper Gila Valley are watered during the dry months by means of underflow from the river sands.



Graph of an underflow test on the Rillito. The horizontal scale is the time scale and the vertical scale is used for the strength of current. The time of salting was 10 03 a. m., and the time of arrival of the salt at the lower well was 11:53 a. m., shown by the two points of inflection.

Where such "accidents of nature" as those mentioned above do not exist, the underflow is to be obtained by pumping.

An alternative to gravity ditches is a submerged dam. Such construction is projected for the Cienega river at a point where a hard quartzite ledge reduces the width of the river channel to 65 feet and the depth of the sands to 12 feet.

The study of a typical underflow stream has been made in the Rillito near old Fort Lowell. Using the Slichter electrical method many determinations of the velocity of underflow have been made. The method in brief consists in injecting an electrolyte into the underflow at one point and determining the time required for it to travel to another point. The progress toward the downstream point and its arrival are separately noted by the increase in resistance offered to electric currents, as shown by the increase in the strength of the currents. The action is shown by the illustration on page 239, which is a graph or plotted record of one of the tests. The casing curve traces the progress of the electrolyte between the upstream, or salt, well and the downstream well. The electrode curve reveals the presence of the salt at and in the lower well Many velocities exceeding 100 feet per day were found, the highest being 575 feet. Hitherto no velocities of groundwater so high as 100 feet per day have been reported. The average velocity through the cross-section near Fort Lowell is taken conservatively at 75 feet per day for the width of the immediate river bed. The direction of the underflow at this point is found in the main to be parallel to the surface flow, though with a considerable lateral component toward the south or right bank.

For obtaining velocities at greater depths than could be reached by hand-driven wellpoints, machine drilling has been employed in two locations. In both places high velocities were observed. They prove that in both the gravity ditches and pumping plants of the Rillito the limit of irrigation is not reached, but that far more water can be developed by going deeper for it, or, in the case of the ditches, by improving and extending the collecting heads. Machine drilling is expensive in power, in skilled labor, and in the upkeep of the drilling rig and must be employed for test purposes sparingly and judiciously.

The groundwater level across the valley between the Rillito and Santa Cruz rivers has been accurately surveyed and a water-contour map of the region has been made. This map, besides indicating the direction of the profound water movement beneath the mesa, also shows the lift for pumping plants in any locality. The fluctuations of the water level in the wells throughout this region have also been observed in order to obtain data on the origin of the groundwater and the rapidity with which the effects of heavy rainfall seasons are felt.

Much material has been gathered for a bulletin on the amount and value of the underflow and upon improved methods of developing it for irrigation.

RESERVOIR SITES.

Arizona is fortunate in having one of the earliest projects of the U. S. Reclamation Service located on the Salt River The upper face of the dam is now constructed for three-fourths of its length to a height of 22 feet above the original bed of the stream. Aside from the water storage of 1,284,000 acre-feet, there will be generated 12,300 electrical horsepower which will be used for pumping plants in the Salt and Gila valleys.

It is probable that the future will see several storage projects developed in Arizona, but on the whole little is known so far of the possibilities along this line. Three reservoir sites have been surveyed in the Catalina Mountains, in Sabino, Bear, and Cebadillo cañons. They are not of sufficient extent to store water for a large acreage, but since these projects contemplate falls of 800, 1,500, and 700 feet, respectively, they can furnish power for a great many pumping plants in the Santa Cruz and Rillito valleys. The power derived from one acre-foot of water falling 800 feet will theoretically lift 40 acre-feet of water through a height of 20 feet. On the Sabino project continuous run-off data have been kept since July, 1903.

A reservoir is under construction 25 miles south of Tucson on the east slope of the Sierrita Mountains. It is situated in a valley drained by a small wash, the flow of which is never large. Water from a neighboring mountain stream is deflected into it. The dam is composed wholly of earthy materials, and is completed

to a height of 40 feet. The projected height is 60 feet and the storage is expected to reclaim 1,000 acres.

GAUGING THE SANTA CRUZ RIVER.

In cooperation with the hydrographic service of the U. S. Geological Survey, gaugings of the Santa Cruz River have been made since October, 1905. The total flow for 1906 and 1907, together with rainfall and run-off percentage, is as follows:

Year.	Acre-feet	Depth in inches distributed over watershed.	Rainfall.	Run-off percentage
1906	14800	0.13	15	0.9
1907	28450	0.25	18	1 4

The precipitation as given is approximated from a study of the rainfall records at the nearest points where such records were taken during the two years.

These low run-off percentages are without parallel except in desert regions. Practically all of the rainfall is evaporated from the watershed or escapes by underground channels.

There are surface flows in the river at the San Xavier Mission and at Tucson. The former is used by the Papago Indians and the latter is diverted by the Farmers' Ditch. The flow is very variable from year to year, and the Farmers' Ditch should be fortified by a pumping plant for tiding over the dry years.

Incidental to the river gaugings some observations were taken on the scour of the river bed during floods, more particularly just west of Tucson at the West Congress Street bridge. The deep and rapid scouring there observed has a bearing on the depth at which bridge piers should be placed and on the depth to which underflow collecting flumes should be buried. It also indicates the great danger in fording such streams when in a swollen condition, for on account of the muddiness of the flood-water the traveler can never know the depth of the scour.

PUMPING FOR IRRIGATION.

New installations of pumping plants have been very numerous during the last two years, and it is becoming very apparent

that a well arranged pumping plant, combined with judicious and energetic farming, is an excellent investment.

The pumping outfit that is usually being selected for single ranches consists of a gasoline engine belted to a centrifugal pump. These plants merit their popularity because of their faculty of running with scarcely any attendance. The irrigator starts his engine in ten minutes or less, and spends a like interval occasionally in oiling the bearings. The fuel bills run high, however, at the present price of the distillate (21 cents per gallon) and make a serious charge, especially upon hay and grain irrigation.

Several new forms of power offer hope of improving these conditions. One is the latest form of crude oil gas-generator which is believed to furnish a gas free from tar and suitable for gasoline engines. Another is the suction gas-producer plant which can be built in units from 15 horsepower up. Even with Arizona prices for anthracite coal it is believed to offer the cheapest and most feasible power for plants ranging from 17 to 50 horsepower.

Another pertinent recommendation, applying especially to irrigable districts near lines of railway, is that central electric generating plants be established near the railways for furnishing power to all the individual pumping plants in their vicinity. One engineer for the central plant and perhaps a "zanjero" to care for the scattered pumping plants can provide water for a large acreage.

Many pumping tests have been made on plants now in operation in the vicinity of Tucson to obtain the following information:

1. The water bearing capacity of the well formations.
2. The efficiencies of different types of plants.
3. The cost of pumping per acre irrigated.

In many cases the efficiency of the plant has been found very low, owing to poor design. In several cases the fuel consumption has been found needlessly doubled by defects that might be remedied for a few dollars.

Material has been gathered for a forthcoming paper on pumping plants, and it is hoped to make the paper of great ser-

vice to irrigators who are running or who contemplate pumping plants.

Much difficulty is being experienced in sinking wells through sand and gravel formations. Wood is usually employed for casing above the water level, and perforated steel cylinders below. Experiments are planned and are now under way in an effort to find a well curbing which shall at the same time be more easily sunk, more enduring, and cheaper than the ones referred to.

CEMENT PIPE FOR SMALL IRRIGATING SYSTEMS.

Bulletin No. 55, under this title, was published as the result of observations of great waste and loss of water from irrigating ditches. It describes experimental pipe of various compositions made at the University, and gives capacity tables and cost data for convenient use in designing pipe lines. The adaptability of cement pipe to several other purposes about the ranch and to city sewers is also pointed out.

River training works will be a feature of some importance in irrigation engineering in southern Arizona. The rainfall of 1907 has been moderate and floods have not been destructive. Considerable work, however, has been done in repairing the damage done by the floods of 1905. The protective works being constructed will be watched with interest to determine their efficacy.

G. E. P. SMITH,
Irrigation Engineer.

COMPLETE LIST OF BULLETINS, ANNUAL REPORTS, AND TIMELY HINTS FOR FARMERS, OF THE ARIZONA AGRICULTURAL EXPERIMENT STATION.

VOL. I.

* Bul. 1, December 1, 1890. Arizona Agricultural Experiment Station (organization).
* FIRST ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1890.
* Bul. 2, September 15, 1891. Notes on Some of the Range Grasses of Arizona. Overstocking the Range.
* " 3, October, 1891. Irrigation in Arizona.
* " 4, November, 1891. Waters and Water Analysis.
* SECOND ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1891.
Bul. 5, April, 1892. Canaigre.
" 6, April, 1892. Soils and Waters.
* THIRD ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1892.
* Bul. 7, February, 1893. Canaigre.
* " 8, March, 1893. Cattle Feeding.
* " 9 November, 1893. Insects and Insecticides.
* " 10, December, 1893. Experimental Work at Willcox.
* " 11, December 1893. Agricultural Development in Southwestern Arizona. Pumping Water for Irrigation.
* FOURTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1893.
* Bul 12, June 30 1894. Preliminary Report of Observations on the "Crown-Knot"
* FIFTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1894.
* Bul. 13, March 1, 1895. The Mesquite Tree: Its Products and Uses.
* " 14, June 1, 1895. Notes on Scale Insects in Arizona.
* " 15, June, 1895. List of Varieties of Fruits.
* " 16, June, 1895 Notes on Apricots at Phoenix Station.
" 17, October, 1895. Agricultural Convention, Part I.
" 18, December, 1895. Agricultural Convention, Part II.
" 19, SIXTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1895.
* " 20, June, 1896. Arizona Weather.
* " 21, July, 1896. Canaigre.
* " 22, January, 1897. Something about Weeds.
* " 23, January, 1897 Sugar Beets
* " 24, SEVENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1896
* " 25, EIGHTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1897.
Index to Vol. I.

VOL. II.

* Bul. 26, December, 1897. Sugar Beet Experiments.
* " 27, December, 1897. Arizona Weather and Climate.
" 28, March, 1898. Salt River Valley Soils.
* " 29, June, 1898. The Date Palm.
* NINTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1898.
* Bul. 30, January, 1899. Sugar Beet Experiments during 1898.
* TENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1899.
* Bul. 31, December, 1899. Sugar Beet Experiments during 1899.
* " 32, December, 1899. Some Insect Pests of Salt River Valley and the Remedies for Them.
Index to Vol. II.

VOL III.

* Bul. 33, April 13, 1900. An Inquiry into the Cause and Nature of Crown-Gall
* " 34, June 30, 1900. Timely Hints for Farmers. Collected Edition, containing Nos. 1 to 18, inclusive.
" 35 August 15, 1900. Vegetable Growing in Southern Arizona.
* ELEVENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1900.
Bul. 36, March 30, 1901. Experimental Work with Sugar Beets during 1900.
" 37, May 25, 1901. Winter Irrigation of Deciduous Orchards.
* " 38, July 20, 1901. Timely Hints for Farmers Collected Edition, containing Nos. 19 to 34, inclusive.
* " 39, August 20 1901. Dairy Herd Records
TWELFTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1901.
* Bul. 40, May 1, 1902. Soil Survey in Salt River Valley.
Index to Vol. III.

VOL. IV.

* Bul. 41, May 26, 1902. Irrigation at the Station Farm, 1898–1901.
" 42, June 14, 1902. The Cool Side of a House in Arizona.
" 43, July 28, 1902. Utilizing our Water Supply
" 44, September 30, 1902. The River-Irrigating Waters of Arizona—Their Character and Effects.
* " 45, November 20, 1902. Timely Hints for Farmers. Collected Edition containing Nos. 35 to 41, inclusive
* THIRTEENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30 1902.
* Bul. 46, October 12, 1903. The Underground Waters of Arizona—Their Character and Uses.
" 47, November 28, 1903. Timely Hints for Farmers Collected Edition, containing Nos. 42 to 47, inclusive.
* FOURTEENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1903.
Bul. 48, June 10, 1904. Relation of Weather to Crops.
" 49, November 28, 1904, Cost of Pumping for Irrigation
FIFTEENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1904.
Bul. 50, May 30, 1905. Steer Feeding Experiments.
" 51, June 30, 1905. Timely Hints for Farmers. Collected Edition, containing Nos 48 to 54, inclusive.
Index to Vol. V.

VOL. V.

SIXTEENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1905.
Bul. 52, May 21, 1906. Alfilaria, *Erodium cicutarium*, as a Forage Plant in Arizona.
" 53, September 20, 1906. Irrigating Sediments and Their Effects upon Crops
" 54, November 26, 1906. Timely Hints for Farmers. Collected Edition, containing Nos. 55 to 59 inclusive.
SEVENTEENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1906.
Bul. 55, July 1, 1907. Cement Pipe for Small Irrigating Systems and Other Purposes.
" 56, September 23, 1907. The Scale Insects of the Date Palm *and* The Extermination of Date-Palm Scales.
EIGHTEENTH ANNUAL REPORT, FISCAL YEAR ENDING JUNE 30, 1907.

* Supply exhausted.

TIMELY HINTS FOR FARMERS.—Separates.

No 1, October 1, 1899. Green-manuring Plants for Orchards.
" 2, October 16, 1899. Planting Eucalypts in Arizona.
" 3, November 1, 1899. Improvement of Arizona Soils.
' 4, November 15, 1899. Winter Irrigation of Orchards
' 5, December 1, 1899. The Crown-Gall.
' 6, December 15, 1899. Desirable Varieties of Peaches.
" 7, January 1, 1900. The Danger of Introducing Insects on Trees
" 8, January 15 1900. What to Plant on Arbor Day.
' 9, February, 1, 1900. Winter Remedies for Injurious Insects.
' 10, February 15, 1900. Care of Milk for the Factory.
" 11, March 1, 1900. Black Alkali.
" 12, March 15, 1900. White Alkali.
' 13, April 1, 1900. Selecting Dairy Cows.
' 14, April 15, 1900. The "Adobe Hole."
' 15, May 1, 1900. Dehorning Cattle
' 16, May 15, 1900. Date-Palm Culture—A Word in Time.
' 17, June 1, 1900. Summer Cultivation.
" 18, June 15, 1900. Grazing versus Irrigation
(Also contained in Bul. 34.)
' 19, October 1, 1900. The Farmers' Reading Course.
' 20, October 15, 1900. Stinking Smut of Wheat and Its Prevention.
21, November 1, 1900. The Use of Chemical Preservatives in Milk.
' 22, November 15, 1900. The Open Range and the Irrigation Farmer.
23, December 1, 1900. The Value of a Dairy Herd Record.
' 24, December 15, 1900. The Use of the Babcock Test
' 25, January 1, 1901. Plant-lice.
" 26, January 15, 1901. Suggestions Concerning Date Culture.
' 27, February 1, 1901. The Spring Vegetable Garden.
' 28, February 15, 1901. Some Trees and Plants for Barren Places.
" 29, March 15, 1901. The Use of Hand Separators on the Farm.
" 30, April 1, 1901. Well Waters for Irrigation.
" 31, April 15, 1901. Home-made Fertilizers.
' 32, May 15, 1901. Wild Barley.
" 33, June 1, 1901. The Australian Saltbush in Arizona
" 34, July 1, 1901. Millets.
(Also contained in Bul. 38.)
" 35, October 15, 1901. Something Worth Knowing about Mud.
No. 36, November 15, 1901. Legumes for Forage and Green-Manuring.
" 37, December 15, 1901. Sugar Beets for 1902.
" 38, January 15, 1902. The Dairy Cow and the Weather.
" 39, March 10, 1902. Extermination of Gophers and Ants.
" 40, April 15, 1902. Observations on "The Rise of the Alkali"
" 41, June 10, 1902. The Fog-fruit or *Lippia Nodiflora* as an Economic Plant.
(Also contained in Bul. 45.)
" 42, October 20, 1902 Strawberry Culture
" 43, December 15, 1902. Skim Milk for Pigs
" 44 January 25, 1903. Watermelon Growing.
" 45, March 1, 1903. Combating the Flat-headed Borer.
" 46, April 15 1903. The Melon Plant-louse and the "Manteca" Disease.
" 47, May 1, 1903. The Use of Branding Fluid.
" 48, October 1, 1903. Bee-products in Arizona.
" 49, October 15, 1903. Sugar-Beet Culture
" 50, December 16, 1903 Some Practical Suggestions Concerning Seed Germination
" 51, January 25, 1904. Potato Culture.
" 52, May 4, 1904. Singed Cactus a Forage
" 53, October 1, 1904. Pickling Olives for Home Use.
" 54, January 30, 1905. Pea Culture.
(Also contained in Bul 51.)
" 55, September 10, 1905 Some Practical Suggestions Concerning Seed Testing
" 56, February 10, 1906 Making the Most of a Small Water Supply.
" 57, April 20, 1906. Weirs for Irrigating Streams.
" 58, June 15, 1906. Observations on Millets.
" 59, June 30, 1906. Field Corn in Arizona.
(Also contained in Bul 54)
" 60, July 30, 1906. Honey Vinegar.
" 61, December 1, 1906. Disk-harrowing Alfalfa.
" 62, January 1, 1907. Suggestions for Arbor Day Planting.
" 63, January 15, 1907. A Lesson in Intensive Farming.
" 64, February 15, 1907. Suggestions for the Control of the Codling Moth.
" 65, May 15, 1907. Contagious Abortion in Cattle.
" 66, August 25, 1907. Observations on Nurse Crops for Alfalfa.
" 67, December 28, 1907. Pumping Plants for Irrigators.

* Supply exhausted.