STATION BULLETIN 277 MAY 1931

Preliminary Report on

Effect of Irrigation on Major Berry Crops

In the Willamette Valley

Agricultural Experiment Station
Oregon State Agricultural College
CORVALLIS

OREGON STATE BOARD OF HIGHER EDUCATION

Hon. C. L. STARR, President.....*Portland*

Hon. Herman Oliver.....*Canyon City*
Hon. C. C. Colt.....*Portland*
Hon. B. F. Irvine.....*Portland*
Hon. E. C. Sammons.....*Portland*
Hon. Albert Burch.....*Medford*
Hon. E. C. Pease.....*The Dalles*
Hon. F. E. Callister.....*Albany*
Hon. Cornelia Marvin Pierce.....*La Grande*

Dr. E. E. Lindsay, Executive Secretary.....*Salem*

STAFF OF AGRICULTURAL EXPERIMENT STATION

W. J. Kerr, D.Sc., LL.D.....*President*
J. T. Jardine, B.S.....*Director*

H. P. Barss, S.M...*Plant Pathologist in Chg.*
F. D. Bailey, M.S...*Asso. Pathologist. Insecticide and Fungicide Bd., U. S. D. of A.*
R. S. Besse, M.S.....*Associate in Farm Mgt.*
F. M. Bolin, D.V.M...*Assistant Veterinarian*
W. B. Bollen, Ph.D.....*Ass't Bacteriologist*
A. G. Bouquet, M.S.....*Horticulturist (Vegetable Crops)*
P. M. Brandt, A.M.....*Dairy Husbandman in Charge*
E. N. Bressman, M.S.....*Assoc. Agronomist*
G. G. Brown, B.S.....*Horticulturist, Hood River Branch Exp. Station, Hood River*
W. S. Brown, M.S.....*Horticulturist in Chg.*
D. E. Bullis, M.S.....*Assistant Chemist*
A. S. Burrier, M.S.....*Assistant in Farm Management*
J. C. Burtner, B.S...*Asso. Dir., News Service*
C. D. Byrne, M.S.....*Director, News Service*
Leroy Childs, A.B.....*Superintendent Hood River Branch Exp. Station, Hood River*
Grace M. Cole, A.B.....*Ass't Botanist Seed Lab., U. S. Dept. of Agric. (Seed Analyst)*
D. Cooter.....*Orchard Foreman*
G. V. Copson, M.S...*Bacteriologist in Charge*
G. M. Darrow, Ph.D.....*Sr. Pomologist in Charge Small Fruit Inves., Hort. Crops and Dis., U. S. Dept. of Agric.*
H. K. Dean, B.S.....*Superintendent Umatilla Branch Exp. Station, Hermiston*
E. M. Dickinson, D.V.M.....*Assistant Poultry Pathologist*
W. H. Dreesen, Ph.D.....*Ag'l Economist*
T. P. Dykstra, M.S.....*Assistant Plant Pathologist, U. S. Dept. of Agriculture*
F. M. Edwards, B.S.....*Asst. Animal Husbandman, East. Ore. Br. Exp. Sta., Union*
A. E. Engbretson, B.S.....*Superintendent John Jacob Astor Br. Exp. Sta., Astoria*
F. E. Fox, M.S...*Asso. Poultry Husbandman*
L. G. O. Gentner, M.S.....*Associate Entomologist., So. Ore. Br. Exp. Station, Talent*
D. G. Gillespie, M.S.....*Asst. Entomologist Hood River Branch Experiment Station*
L. N. Goodding, B.A., B.S.....*Associate Plant Pathologist, U. S. Department of Agric.*
D. M. Goode, B.A.....*Associate Editor*
J. R. Haag, Ph.D.....*Chemist (Animal Nut.)*
H. Hartman, M.S.....*Horticulturist (Pom.)*
E. M. Harvey, Ph.D.....*Horticulturist (Phys.*
D. D. Hill, M.S.....*Associate Agronomist*
F. G. Hinman, M.S.....*Jr. Entomologist. Stored Prod. Insects, U. S. Dept. of Agric.*
C. J. Hurd, B.S.....*Ass't Ag'l Engineer*
R. E. Hutchison, B.S.....*Assistant to Supt. of Harney Valley Br. Exp. Sta., Burns*
G. R. Hyslop, B.S.....*Agronomist in Charge*
W. T. Johnson, D.V.M...*Poultry Pathologist*
I. R. Jones, Ph.D...*Assoc. Dairy Husband'n*
J. S. Jones, M.S.A.....*Chemist in Charge*
S. Jones, M.S.....*Asst. Entomologist*
F. L. Knowlton, B.S.....*Poultry Husbandman*
G. W. Kuhlman, M.S.....*Assistant in Farm Management*
A. O. Larson, M.S.....*Entomologist, Stored-Prod. Insects, U. S. Dept. of Agric.*
M. R. Lewis, C.E.....*Irrigation and Drainage Specialist; Agricultural Engineer, Bureau of Public Roads, U. S. Dept. of Agric.*
A. G. Lunn, B.S.....*Poultry Husbandman in Charge*
A. M. McCapes, D.V.M...*Asst. Veterinarian*
F. P. McWhorter, Ph.D.....*Asso. Plant Pathologist*
J. F. Martin, B.S.....*Jr. Agron., Office of Cereal Crops and Diseases, U. S. D. of A.*
P. W. Miller, Ph.D.....*Assoc. Plant Pathologist, Hort. Crops and Dis., U. S. D. of A.*
H. H. Millsap.....*Agent, Bureau of Plant Industry, U. S. Dept. of Agric.*
G. A. Mitchell, B.S.....*Assistant Agronomist, Office of Dry-Land Agric., U. S. D. of A.*
D. C. Mote, Ph.D.....*Entomologist in Chg.*
O. H. Muth, D.V.M...*Assistant Veterinarian*
M. N. Nelson, Ph.D.....*Agricultural Economist in Charge*
O. M. Nelson, M.S.....*Animal Husbandman*
A. W. Oliver, M.S.....*Assistant Animal Husbandman*
M. M. Oveson, B.S.....*Asst. to Supt., Sherman County Br. Exp. Sta., Moro*
E. L. Potter, M.S.....*Animal Husbandman in Charge*
W. L. Powers, Ph.D.....*Soil Scientist in Chg.*
F. E. Price, B.S.....*Agricultural Engineer*
E. T. Reed, B.S., A.B.....*Editor*
F. C. Reimer, M.S.....*Superintendent Southern Oregon Br. Exp. Station, Talent*
R. H. Robinson, M.S.....*Chemist, Insecticides and Fungicides*
C. V. Ruzek, M.S.....*Associate Soil Scientist (Fertility)*
H. A. Schoth, M.S.....*Associate Agronomist, Forage Crops, U. S. Dept. of Agric.*
C. E. Schuster, M.S.....*Horticulturist, Hort. Crops and Dis., Bureau of Plant Industry, U. S. Dept. of Agric.*
H. D. Scudder, B.S...*Chief in Farm Man'g't*
O. L. Searcy, B.S.....*Technician, Vet. Med.*
H. E. Selby, B.S.....*Associate in Farm Mgt.*
O. Shattuck, M.S.....*Superintendent Harney Valley Branch Experiment Sta., Burns*
J. N. Shaw, B.S., D.V.M...*Asst. Veterinarian*
J. E. Simmons, M.S.....*Asso. Bacteriologist*
B. T. Simms, D.V.M...*Veterinarian in Chg.*
R. Sprague, Ph.D.....*Assisitant Pathologist, U. S. Dept. of Agric.*
D. E. Stephens, B.S.....*Superintendent Sherman County Branch Exp. Station, Moro*
R. E. Stephenson, Ph.D.....*Associate Soil Scientist*
G. L. Sulerud, M.A.....*Asst. Ag'l Economist*
B. G. Thompson, M.S.....*Asst. Entomologist*
E. F. Torgerson, B.S.....*Assistant Soil Scientist (Soil Survey)*
R. B. Webb, B.S.....*Agent, Cereal Crops and Dis., U. S. Dept. of Agric., Sherman Co. Br. Station*
C. F. Whitaker, B.S.....*Assistant Chemist*
E. H. Wiegand, B.S.....*Horticulturist (Horticultural Products)*
Joseph Wilcox, M.S.....*Asst. Entomologist*
Maud Wilson, B.S.....*Home Economist*
Gustav Wilster, Ph.D.....*Associate in Dairy Manufacturing*
Robt. Withycombe, B.S.....*Superintendent Eastern Oregon Br. Exp. Station, Union*
R. A. Work, B.S...*Asst. Irrigation Engineer, Div. of Ag'l Engineering, U. S. D. of A.*
S. M. Zeller, Ph.D.....*Plant Pathologist*

TABLE OF CONTENTS

TABLE OF CONTENTS—*Continued*

SUMMARY

1. This bulletin is divided into two parts. Part I presents the results of a 5-year test on the Experiment Station farm at Corvallis of the effect of irrigation on cost of establishing, cost of production, yield, income, size of berry, cane growth, time of ripening, and canning quality of small fruit crops in the Willamette Valley. Part II presents suggestions on practical irrigation problems for the berry irrigator.

2. Irrigation water was pumped from a well consisting of a pit 20 feet deep with two perforated casings extending 30 feet deeper and equipped with a 5-inch centrifugal pump directly connected to a 10-horse-power motor. The total cost of the well and irrigation equipment was $2,674.

3. Producing small-fruit crops under irrigation, with the exception of Ettersburg 121 strawberry, proved to be more profitable than growing them without irrigation. The profit advantage in irrigation is sufficiently great to offset possible inaccuracies in this test and the apparent disadvantages of small-plot experiments.

Evergreen Blackberries

4. It cost $65 per acre more to bring the irrigated Evergreen blackberries into bearing at two years of age than it did the non-irrigated planting.

5. The average cost per acre for the three bearing years, 1928, 1929, and 1930, was 43 percent higher for the irrigated Evergreen blackberries than it was for the non-irrigated crop.

6. The production from the irrigated plantings was 69 percent larger than that harvested from the non-irrigated vines.

7. The net income per acre during the three-year bearing period from the irrigated Evergreen blackberries was more than three times the net returns obtained from the non-irrigated crop.

8. The berries from the irrigated vines averaged 30 percent larger in size than those produced from the dry plots.

9. Irrigation increased materially the cane growth of the Evergreen blackberry plants and hastened the ripening date. A larger portion of the irrigated berries ripened in the earlier part of the season than of the fruit grown from the non-irrigated vines.

Red Raspberries

10. Although it cost $70 per acre more to establish the irrigated red raspberries at two years of age than it did the non-irrigated berries the net income obtained from the irrigated berries during the three-year-bearing period was more than double that received from the non-irrigated fruit.

11. Irrigation increased the size of the berries 7 percent but did not retard time of ripening.

12. The quality of the canned berries from the irrigated plots was fully as good as it was from the berries grown without irrigation.

LOGANBERRIES

13. In this test only one year was required to establish the loganberry planting and bring it into commercial production.

14. The yield from the irrigated berries the second and third years of growth, respectively, was double that obtained from the non-irrigated berries. The crop on both the irrigated and the non-irrigated plantings the fourth year was killed by frost.

15. The irrigated berries made an average profit of $60.26 per acre per year during the two bearing years while the non-irrigated fruit sustained an average loss of $13.64 per acre per year.

16. Irrigated loganberries were 35 percent larger than those grown without irrigation.

17. Cane growth of loganberry plants was greatly increased by irrigation.

18. Irrigation slightly retarded time of ripening of loganberries.

19. The canning quality of loganberries was improved by irrigation.

BLACK RASPBERRIES

20. Although this test shows that irrigation of black raspberries increased the yield and the returns, both the irrigated and the non-irrigated crops were produced at a heavy loss for the three-year bearing period.

21. Under the conditions of this experiment the production of black raspberries either with or without irrigation must be considered as unprofitable.

22. Irrigated black raspberries were 22 percent larger in size than were the non-irrigated fruits.

23. Cane growth on black raspberries is greatly increased by irrigation. Good plant vigor, as indicated by increased cane growth, did not apparently increase immunity toward disease.

24. Irrigation did not materially affect the quality of canned black raspberries.

STRAWBERRIES

25. Irrigation was profitable with the Marshall variety, but with the Ettersburg 121 variety it was not. Irrigation doubled the average net income of the Marshall variety and decreased the net income of the Ettersbury 121 variety 50 percent.

26. Irrigation tended to delay the ripening of the Marshall strawberries, but hastened the ripening date of the Ettersburg 121 variety.

27. Under irrigation it appears practicable to plant some varieties of strawberries in the summer after spring-planted crops have been harvested from the land.

Preliminary Report on the

Effect of Irrigation on Major Berry Crops

In the Willamette Valley *

By

C. E. SCHUSTER, R. S. BESSE, G. L. RYGG, and W. L. POWERS

Part I

INTRODUCTION

This bulletin is divided into two parts. Part I presents the results obtained in experimental tests at Corvallis designed to determine the effect of irrigation on the production of small-fruit crops in the Willamette Valley. It is a progress report of the results of irrigation for the first five years of growth of these crops. The report indicates the influence of irrigation on cost of production, which is a paramount problem confronting the growers of small fruits. The grower's safety in increasing production or his survival in periods of low prices is dependent largely on his ability to produce at a low cost.

Part II presents practical suggestions for the grower who wishes to irrigate his berry crop. This section of the report is not based entirely on the results of the experiment reported in Part I since the data in that experiment do not cover many practical irrigation problems on which the prospective irrigator desires information. Instead, these suggestions represent the judgment and experience of the authors in practical irrigation problems.

History. The extent to which irrigation might be made to reduce cost of small-fruit production in the Willamette Valley was unknown prior to 1926, although minor experimental tests conducted by the Oregon Agricultural Experiment Station over a number of years had indicated the economic feasibility of irrigation. Farmers here and there had also attempted the irrigation of small tracts with promising results. Aside from these preliminary tests, however, practically no results of experimental work on the irrigation of small fruits under Northwest conditions had been available for the fruit growers. Questions as to the effect of irrigation on the factors of cost, yield, income, quality of fruit, investment requirement, and other problems connected with irrigation, could not be answered until actual tests under Willamette Valley conditions had been made.

*Acknowledgments. Acknowledgment is due Professors H. D. Scudder, Chief in Farm Management; W. S. Brown, Horticulturist in Charge; M. R. Lewis, Irrigation and Drainage Engineer; C. V. Ruzek, Associate Soil Scientist; and A. S. Burrier, Assistant in Farm Management, for valuable counsel, criticisms, and suggestions.

Purpose of the experiment. The purpose of this experiment was to determine (1) the feasibility of pumping water from wells for the irrigation of crops and (2) the effects of irrigation on production, including: (a) cost of production, (b) gross income per acre, (c) profit per acre, (d) yields per acre, (e) quality of fruit, (f) cane growth and vigor of plants, (g) size of berries, and (h) date of ripening.

PLAN AND ORGANIZATION OF THE EXPERIMENT

THE SOIL

For the purpose of testing the effect of irrigation on the production of small fruits, the Oregon Agricultural Experiment Station, in cooperation with the Oregon Committee on the Relation of Electricity to Agriculture established an irrigation experiment on river-bottom soil on the Experiment Station farm early in 1926. The ground selected for the small fruit crops was typical river-bottom soil of the Newberg and Chehalis series, of which there are approximately 300,000 acres in the state. This group of soils is known to be of an open, friable nature, with a moderately compact, sandy loam subsoil, and when leveled is suitable for irrigation. In areas where these soils are too rolling for practical leveling, irrigation by sprinkling may be feasible. Although leveling was continued until irrigation was feasible, effort was made to remove as little soil as possible in order that the lower, less fertile layer of soil would not be brought too near the surface. Although the land had been used for growing grain for some years past, no fertilizer was used before setting to the different fruit crops. Heavy applications of manure from 15 to 20 loads per acre per year, however, have been put on the ground since establishing these crops.

ARRANGEMENT OF PLOTS

A unit of six acres devoted to a combination of strawberries and bramble fruits was developed in an arrangement such as to provide a maximum continuous labor income and the most complete use of labor and equipment throughout the growing season.

Each plot of cane fruit consisted of 4 rows 9 feet apart and 264 feet long, comprising 22/100 of an acre. The distance apart in the row varied for each kind of fruit. Black raspberries were set 4 feet apart; red raspberries, 30 inches; loganberries, 9 feet; and Evergreen blackberries, 15 feet apart in the row. Strawberries were at first set 3 feet by 3 feet, but that spacing did not give enough plants per acre under irrigation, so the Marshall and Gold Dollar varieties were allowed to make matted rows. It was found that 3 feet between the rows was not distance enough for matted rows under irrigation. In later plantings the rows have been spaced 42 inches apart with 15 inches between the plants, but no matted rows have been used.

Dry and irrigated plots of strawberries were completely separated so no effects of irrigation were ever felt on the non-irrigated strawberries. With the cane fruits the irrigated plots were separated from the non-irrigated plots by 18 feet, or by leaving out one row. The space thus vacated was planted to odd varieties of cane fruits. This distance between irrigated and non-irrigated plots was thought to be sufficient to aid in absorbing any

side drift of water that might occur. Unfortunately this was not always the case, as there appeared to be a decided increase in yields on the lower end of the dry plot of blackberries, indicating that it was receiving extra moisture from some source. The place where this increase in yield was observed was at the farthest point 42 feet from the nearest ditch or furrow. Some side drift may also have occurred with red raspberries but in no particular spot. The other cane fruits show no evidence of extra water in the dry plots. As a result of this apparent seepage of irrigation water into some of the dry plots, the data presented may not be correct as to the exact difference between irrigated and non-irrigated berries, but even then the difference is still great enough to show the advantage from irrigation.

Each kind of fruit was established, brought into bearing, and with the exception of loganberries and strawberries, three crops were harvested by the close of 1930. Careful accounts of all labor and other costs incident to the establishment and production of these crops were recorded, summarized, and analyzed.

IRRIGATION FACILITIES AND PRACTICE

The irrigation well. A well pit 6 by 8 feet was dug 20 feet deep and two 30-foot holes 8 inches in diameter were drilled in the bottom of this pit. A pumping unit consisting of a 5-inch centrifugal pump, directly connected to a 10-horse-power motor, was placed in this well 18 feet below the surface of the ground.

Cost of well and irrigation equipment. Table I presents the cost of digging the well, purchasing and installing the equipment, and preparing the distribution system ready for use.

Undoubtedly the size of the well pit and the cost of the whole installation were considerably higher than might be necessary under practical farm conditions.

TABLE I. COST OF WELL AND IRRIGATION EQUIPMENT

Item	Cost
Well	
Digging and cribbing well pit (6'x8'x20')	$483.89
Drilling and casing two 30-foot holes, 8 inches in diameter at bottom of pit (casing perforated)	341.30
Cementing walls of well pit	311.38
Pumping unit	
10-horse-power motor and 5-inch Fairbanks-Morse pump	440.00
Fittings and installation	497.84
Distribution system	
Concrete pipes, valves, stand-pipes, field laterals, and installation	599.59
Total cost	$2,674.00

Amount and date of irrigation. The pumping of the water from the irrigation well, the application of the water to the land, and the keeping of records of all costs connected with delivering the water in this experiment was under the control of the department of Soils of the Experiment Station. The department of Horticulture was responsible for the planting and handling of the fruit crops grown in the experiment, and the keeping

TABLE II. AMOUNT AND DATES OF IRRIGATION OF BRAMBLE FRUITS

Crop	1926		1927		1928		1929		1930	
	Dates of irrigation	Depth of water applied	Dates of irrigation	Depth of water applied	Dates of irrigation	Depth of water applied	Dates of irrigation	Depth of water applied	Dates of irrigation	Depth of water applied
		Inches		*Inches*		*Inches*		*Inches*		*Inches*
Evergreen blackberries	7/14	5.9	7/24	4.0	6/12–16	12.9	7/5–6–8	6.1	7/1–2†	3.2
	8/14	5.5	8/8	4.0	7/5–7	6.3	7/12*	.9	7/7†	3.2
			8/28	4.0	7/24	3.7	7/23*	2.7	7/25†	3.9
					8/8–13	7.8	8/8*	3.6	8/12†	5.2
					8/18	5.5	8/16	3.6	8/27†	5.6
Total for season		11.4		12.0		36.2		16.9		21.1
Red raspberries	7/9–10	7.5	6/22	4.0	6/9	7.5	6/28–29	7.0	6/18‡	5.4
	7/12		7/19	4.0	7/7	6.4	7/17–18	2.7	7/5	1.9
			8/7	4.0	7/25	3.1	8/7	3.6	7/10‡	3.2
			8/27	4.0	8/15	3.8			7/23‡	3.9
									8/20‡	5.8
Total for season		7.5		16.0		20.8		13.3		20.2
Loganberries	8/13	6.0	7/2	4.0	6/11–12	14.1	7/5–6–8	7.6	7/1–2	3.3
			7/27	4.0	7/7	6.4	7/12	.9	7/7	3.6
			8/8	4.0	7/24	4.0	7/17	1.8	7/25	3.6
			8/28	4.0	8/11–14	5.1	7/23	4.0	8/17–18	3.6
							8/16	3.6		
Total for season		6.0		16.0		29.6		17.9		14.1
Black raspberries	7/12–13		6/22	4.0	6/9–11	11.6	6/29 7/1	9.0	6/19	6.0
		7.5	7/19	4.0	7/7	6.4	7/16	2.3	7/5	1.9
			8/7	4.0	7/27	4.5	7/22	3.6	7/11	2.6
			8/27	4.0			8/7	3.6	7/24	2.6
									8/19	5.8
Total for season		7.5		16.0		22.5		18.5		18.9

*Plots 4 and 5 only.
†Plots 2, 4, and 5 only. Plot 3 irrigated as follows: 7/1—1.9 in.; 7/25—1.9 in.; 8/12—2.9 in.; 8/27—2.8 in. Total for season, 9.5.
‡Plots 2, 3, and 5 only. Plot 4 irrigated as follows: 6/18—1.9 in.; 7/23—2.9 in.; 8/20—3.5 in. Total for season, 8.3.

of production records and itemized costs connected with growing the crops. The department of Farm Management is responsible only for the computations, analysis, and summarizing of the costs and profits of the operations as taken from these records.

Table II presents the different dates of irrigation of the cane fruit plots and the depth in inches of the water applied to the land.

Different amounts of water were applied to the Evergreen blackberry and red raspberry plantings in 1929 and 1930 in a test to determine the comparative effect of heavy and light irrigation. The results of this test will be discussed elsewhere in this report.

Investment per acre in irrigation system and farm equipment. The average investment in the irrigation system and in the farm equipment employed during the first five years of growth of the small-fruit crops was $151.85 per acre for the irrigated plots and $7.00 per acre for the non-irrigated area (Table III).

TABLE III. AVERAGE INVESTMENT PER ACRE IN IRRIGATION SYSTEM AND FARM EQUIPMENT DURING THE FIRST FIVE YEARS OF GROWTH OF IRRIGATED AND NON-IRRIGATED SMALL-FRUIT CROPS

Item	Investment per acre (Other than land and buildings)	
	Irrigated	Non-irrigated
Irrigation well*	$ 59.80	.....
Irrigation equipment†	85.05	.....
Farm machinery	7.00	$7.00
Total	$151.85	$7.00

*Well cost includes cost of digging well pit, cementing well pit, drilling holes at bottom of pit, and cost of perforated well casing.

†Irrigation equipment includes cost of distribution system, pipes, valves, pump, standpipes, fittings, field laterals, and installation.

The investment in land and buildings is not included in this analysis, as the land in this experiment was leased at a cash rental of $15.00 per acre per year. To place a value on the land is not essential since the land cost is fully covered by the rental paid.

The investment per acre in the irrigation system was relatively high in this experiment, owing to the small acreage irrigated. In 1926 only 10.3 acres were watered; in 1927, 18.32 acres; in 1928, 17.48 acres; in 1929, 19.87 acres; and in 1930, 18.28 acres, respectively, were irrigated from this plant. The irrigation system was capable of handling from 80 to 100 acres. Had this been done the average investment per acre and cost of irrigation would have been very materially reduced.

EFFECT OF IRRIGATION ON SMALL-FRUIT CROPS

The economic advantages of the irrigation of small-fruit crops are indicated in the following analysis and presentation of the comparative cost of establishing, cost of production, income, and profit per acre.

There is danger perhaps of over-estimating the advantages of irrigation when conclusions are drawn from small experimental plantings, particularly so when considering only the first five years of growth. Commercial plantings grown under larger field conditions may not show as

favorable advantages from irrigation as those resulting from these experimental tracts.

Undoubtedly the cost of establishing these plantings has been more quickly repaid by the irrigated berries than by those not irrigated. The next five-year period, however, may show somewhat different results, especially if there should be heavier rainfall during the growing season.

Notwithstanding these qualifications and limitations, the feasibility and economic advantages of irrigating bramble fruits are clearly indicated in the larger yields and increased returns obtained in the experimental irrigation of these crops under local conditions.

EVERGREEN BLACKBERRIES

The ground for Evergreen blackberries was plowed in March and leveled for irrigation. The preparation of this land for planting the crop cost $27.27 per acre. In April, 1926, the land was set to Evergreen blackberries in rows 9 feet apart and with the plants 15 feet apart in the rows. The trellis consisted of two parallel wires on cross-arms 40 inches above the ground.

Cost of establishing. In considering the cost of establishing Evergreen blackberries from time of planting to bearing age, the cost for the first two years of growth only is included. Although it is recognized that at two years of age the plantings were not mature, yet the production the third year of growth was large enough to contribute very materially to the cost of maintaining the crop. Consequently the crop was considered of bearing age when it was two years old.

Table IV presents an itemized statement of the annual cost of establishing irrigated and non-irrigated Evergreen blackberries and shows the total cost for the first two years of growth.

TABLE IV. COST PER ACRE OF ESTABLISHING IRRIGATED AND NON-IRRIGATED EVERGREEN BLACKBERRIES

Item	1926		1927		Total cost from planting to bearing age	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Preparing land	$ 27.27	$ 27.27	.....	.....	$ 27.27	$ 27.27
Plants (323 per acre)	4.36	4.36	.....	.....	4.36	4.36
Setting plants	8.95	8.95	$ 2.00	$ 2.00	10.95	10.95
Cultivating	13.32	13.32	34.11	34.09	47.43	47.41
Trellis	59.68	59.68	.....	.....	59.68	59.68
Trellising	.....	.....	16.68	16.68	16.68	16.68
Irrigating—labor only	10.73	.....	8.99	.....	19.72	.....
Power cost for irrigating	5.24	.....	4.20	.....	9.44	.....
Cover-crop seed	.....	.....	1.75	1.75	1.75	1.75
Cover-cropping	.....	.....	2.10	2.09	2.10	2.09
Pruning and training	.....	.....	4.41	4.41	4.41	4.41
Supplies and repairs*	11.36	11.36	16.36	16.36	27.72	27.72
Land rental	15.00	15.00	15.00	15.00	30.00	30.00
Interest (on equipment)	11.90†	.45	6.50	.40	18.40	.85
Depreciation (on equipment)	13.00†	.90	7.71	.90	20.71	1.80
Total cost per acre	$180.81	$141.29	$119.81	$93.68	$300.62	$234.97

Note: Man labor is charged at the rate of 40¢ per hour and horse labor at 13¢ per hour.
*Includes such items as hallocks, crates, carriers, gas, oil, repairs, fruit hauling, and other miscellaneous expenses.
†Heavier first year due to small acreage irrigated.

TABLE V. TOTAL COST, YIELD, INCOME, AND PROFIT PER ACRE FOR FIRST FIVE YEARS OF GROWTH
Irrigated and Non-irrigated
Evergreen Blackberries

Item	Cost of establishing		Three bearing years						Yearly average for three bearing years		Total for five years	
	1926 and 1927		1928		1929		1930					
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Cost per acre (*dollars*)*	300.62	234.97	238.50	168.74	391.14	260.45	441.23	318.31	356.96	249.17	1371.49	982.47
Yield per acre (*pounds*)	.....	.....	4,445	2,377	11,079	5,286	17,133	11,606	10,886	6,423	32,657	19,269
Cost per pound (*dollars*)	.....	.....	.0536	.071	.0353	.0492	.0257	.028	.033†	.039†	.....	.....
Gross income per acre (*dollars*)‡	.....	.....	133.35	71.31	443.16	211.44	856.65	580.30	477.72	287.68	1433.16	863.05
Net income per acre (*dollars*)	.....	.....	−105.15	−97.43	52.02	−49.01	415.42	261.99	120.76	38.51	61.67	−119.42

*For itemized cost per acre see Table XX (Appendix).
†Weighted average cost, each year's cost weighted according to yield.
‡Price received per pound: 1928, 3¢; 1929, 4¢; 1930, 5¢.

It cost $65 per acre more to bring the irrigated berries into bearing than it did the non-irrigated berries. The chief differences in cost of establishing the crops are found in the items of irrigating, electric power, interest, and depreciation. All other costs remain about the same on both the irrigated and the non-irrigated acreage.

Cost, yield, and income per year. After the establishment of the plantings in 1926 and 1927, three successive crops of berries were harvested. During the five years of growth from planting to the close of 1930, both the irrigated and the non-irrigated berries received the same treatment except that one area was irrigated and one was not.

Table V presents a composite picture of the comparative cost, yield, income, and profit per acre of the irrigated and non-irrigated berries for the first five years of growth. Table V gives the summary of the cost of establishing the crop, the average for the three bearing years, and the total for the five-year period.

The average cost per acre for the three bearing years 1928, 1929, and 1930 was 43 percent higher for the irrigated than for the non-irrigated berries. During this bearing period, the irrigated vines produced, however, an average crop 69 percent larger than that grown from the non-irrigated vines and provided a net income per acre of more than three times the net returns received from the non-irrigated crop.

Profit or loss per acre for first five years of growth. The income from the irrigated crop passed the cost-of-production mark one year earlier than it did in the non-irrigated crop. Figure 1 shows the point at which the income was greater than the cost. The profit made or loss sustained during each year of the experiment and the totals for the five-year period are also indicated.

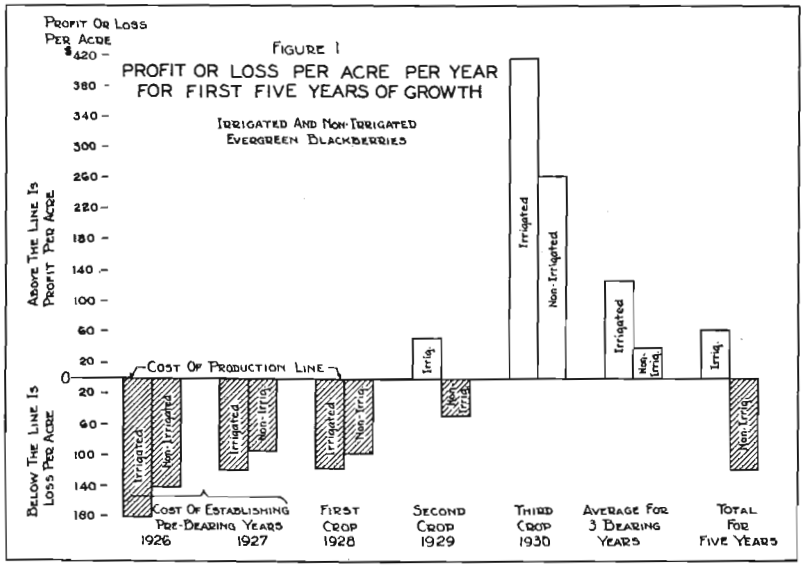

Figure 1.

Figure 1 shows that during the first three years of the life of the crop a loss was sustained in both the irrigated and the non-irrigated berries. In the first two years no commercial production was obtained as the crop was being established during that period. In the third year, although the production was heavy enough to reduce the cost considerably, the production was insufficient to show a profit. The fourth year the income from the irrigated berries passed the cost mark with a margin of $52.02 per acre, while the non-irrigated berries still lagged below the cost-of-production line with a loss of $49.01 per acre. Not until the fifth year did the income from the non-irrigated berries exceed the cost of production and even in that year the profit per acre from the non-irrigated berries was $153.43 per acre less than it was from the irrigated berries.

If all expenses for the five years of growth are deducted from the total income received during that period, there remains a profit of $61.67 per acre for the irrigated, and a loss of $119.42 per acre for the non-irrigated berries. This is a difference of $181.09 per acre in favor of the irrigated crop at the end of the first five years.

Since the Evergreen blackberries were not in full bearing until four years of age, the crop the fifth year was the first full crop produced during this experiment. Up to this period of growth, irrigation has been very beneficial and economically sound. As the study continues a more complete comparison of the economic advantages of irrigation may be made.

Comparative size of berry. The berries, average of all pickings for 1930, were 30 percent larger in size from the irrigated vines than those produced from the dry plots (Figure 2).

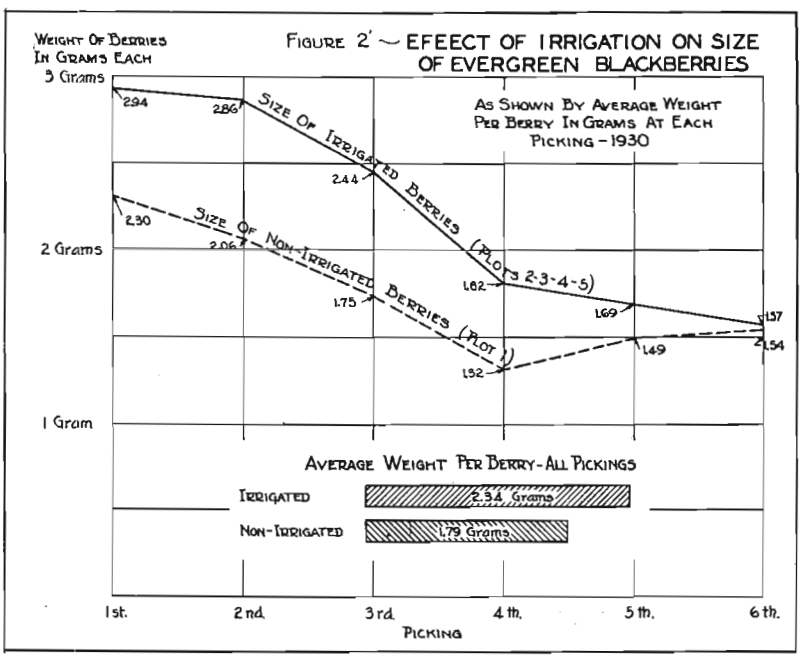

Figure 2.

The irrigated berries were 28 percent larger at the first picking, 39 percent larger at the second picking, 40 percent larger at the third picking, and 38 percent larger at the fourth picking than were the berries which were produced without irrigation.

At the fifth picking, the size of the irrigated berries had decreased to within 13 percent of the size of the non-irrigated berries, and at the sixth picking were only 2 percent larger than the dry berries.

On the other hand, the size of the non-irrigated berries decreased consistently until the time of the fifth and sixth pickings, when the size of these berries increased 13 percent and 17 percent respectively above that prevailing at the time of the fourth picking. This increase in the size of the non-irrigated berry was doubtless due to rainfall which occurred before the last two picking dates.

Comparative cane growth and vigor. Irrigation increases the cane growth of Evergreen blackberries, both as to the length of canes and the number of canes per hill. In view of the fact that Evergreen blackberries are slower in reaching maturity than are other cane fruits, the work of determining the most desirable cane length was delayed until the season of 1930, when all good canes were left on the hills and varying lengths were tested to determine the optimum cane length. In this test it was found that when canes of the same length were left in both the irrigated and the non-irrigated plots the irrigated vines produced 46 percent more marketable fruit than that grown from the dry planting. This increase was due not only to the greater size of the irrigated berry, but also to the greater number of producing canes on the irrigated plots.

On one of the irrigated plots the canes were left at pruning 50 percent greater in length. The yield due to this additional length was increased only 14 percent. This indicates that the increase in yield does not depend entirely on the length of canes, but is also determined by the size of the berries.

Thus far in the experiment no difference between the irrigated and the non-irrigated canes has been noted in the resistance to winter injury. No disease of any kind has been found in the Evergreen blackberry plantings, so no data are available as to the comparative resistance to disease.

Tests were conducted in 1930 in the Evergreen plantings to determine the comparative profit of irrigation with varying amounts of water. One plot was given only 9.5 inches in depth of water while three other plots were given 21.1 inches in depth. The yield on the area receiving the smaller amount of water was 3,097 pounds per acre less than that obtained from the heavily irrigated land. This represented a reduction of $154.85 in income per acre. A similar test in the production of red raspberries showed a corresponding decrease in yield.

The quality of the canned fruit was essentially the same with irrigated and non-irrigated Evergreen blackberries. The only difference was that the irrigated berries were larger and firmer, with a smaller proportion of seed to pulp.

Effect of irrigation on time of ripening. The yield was not only increased by irrigation but a somewhat larger portion of the irrigated berries ripened in the earlier part of the season than did the fruit of the non-

irrigated plots. By the date of the fourth picking 3.6 percent more of the total irrigated crop had been harvested than of the dry-grown fruit (Figure 3).

The percentage of the crop picked at the time of each picking is indicated in Figure 4. At both the first and the second picking dates a larger part of the irrigated fruit was harvested than was gathered from the non-irrigated crop.

FIGURE 3
CUMULATIVE YIELD OF BERRIES AT END OF EACH PICKING AND CUMULATIVE PER CENT OF CROP PICKED

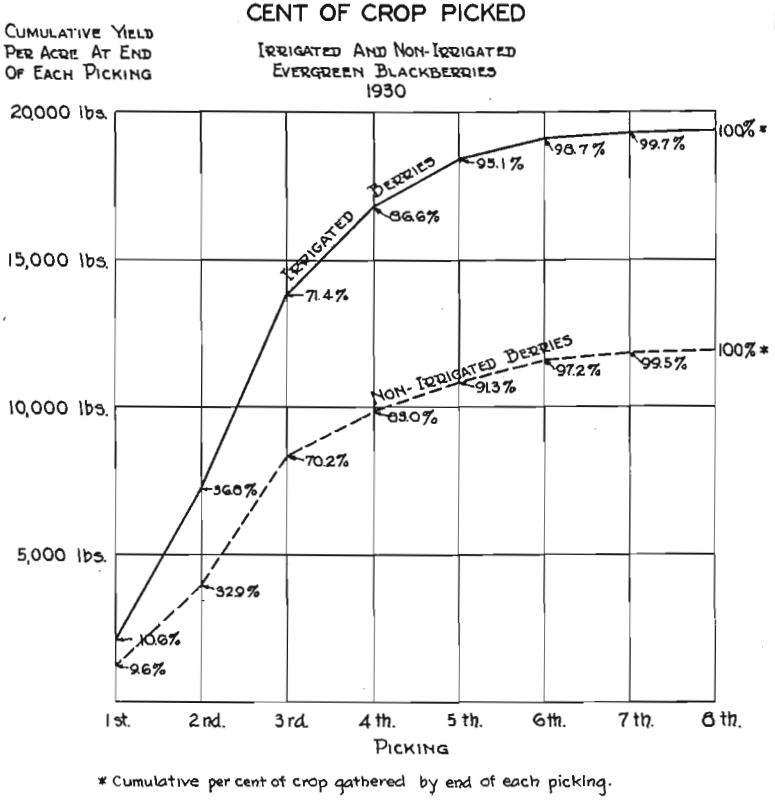

Figure 3.

The third picking was the largest of the season. At that time a slightly larger portion of its total crop was taken from the dry plot than was gathered from the irrigated plot. The total yield per acre up to this time, however, was 5,686 pounds greater from the irrigated than it was from the non-irrigated. During the next two pickings a higher percentage of the irrigated crop was harvested.

This test clearly indicates that, contrary to general opinion, the irrigation of Evergreen blackberries does not delay the time of ripening. It follows therefore that rains, in all probability, will cause no greater loss on irrigated blackberries than on those not irrigated.

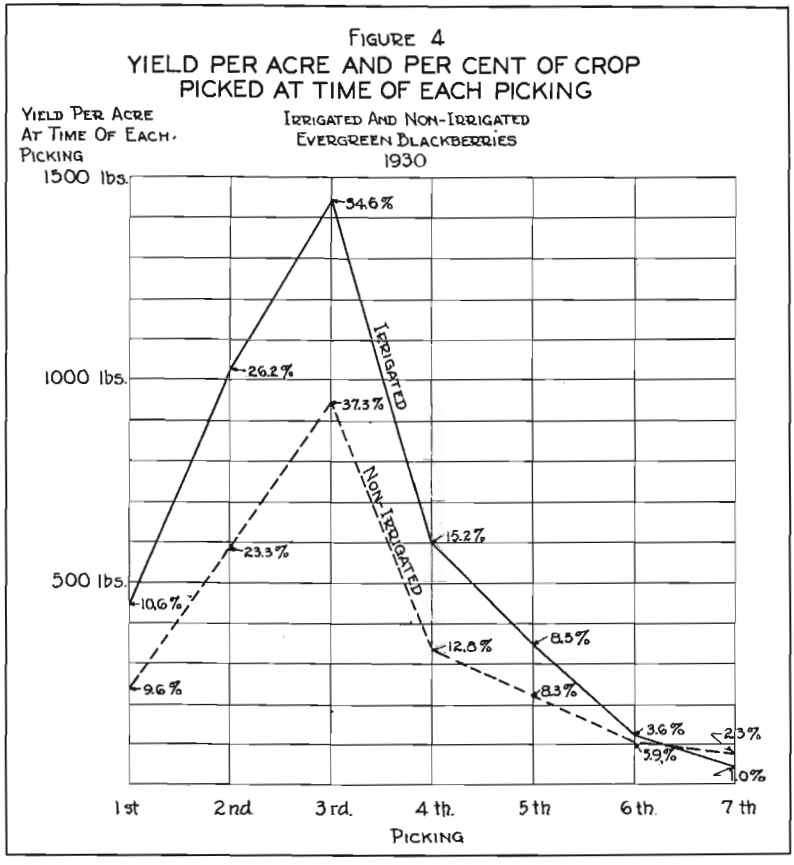

Figure 4.

RED RASPBERRIES

In March, 1926 the ground which was to be used for red raspberries was plowed and leveled for irrigation. In April red raspberry plants of the Cuthbert variety were set in rows 9 feet apart and 2½ feet apart within the rows. The trellis for this crop consisted of two parallel wires stretched on cross-arms 40 inches above the ground.

Cost of establishing. It cost $70.22 more per acre to establish the irrigated red raspberries and carry them to two years of age than it did for the non-irrigated berries (Table VI).

TABLE VI. COST PER ACRE OF ESTABLISHING IRRIGATED AND NON-IRRIGATED RED RASPBERRIES

Item	1926		1927		Total cost to bearing age	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Preparing land	$ 27.20	$ 27.20	.....	.....	$ 27.20	$ 27.20
Plants (1,936 per acre)	20.00	20.00	.....	.....	20.00	20.00
Setting and resetting plants	19.15	19.15	$ 3.18	$ 3.18	22.33	22.33
Cultivating	16.29	15.38	19.90	18.46	36.19	33.84
Trellis material	61.22	61.22	.....	.....	61.22	61.22
Trellising	.....	.....	35.16	35.14	35.16	35.14
Irrigating (labor only)	9.92	.....	12.02	.....	21.94	.....
Power cost for irrigating	5.24	.....	4.20	.....	9.44	.....
Cover-crop seed	.....	.....	1.75	1.75	1.75	1.75
Cover-cropping	.....	.....	1.45	1.45	1.45	1.45
Fertilizing	.....	.....	2.91	2.91	2.91	2.91
Fertilizer	.....	.....	.75	.75	.75	.75
Pruning and training	.....	.....	17.27	17.27	17.27	17.27
Supplies and repairs*	10.90	10.90	16.36	16.36	27.26	27.26
Land rental	15.00	15.00	15.00	15.00	30.00	30.00
Depreciation (on equipment)	13.00†	.90	7.71	.90	20.71	1.80
Interest (on equipment)	11.91†	.45	6.50	.40	18.41	.85
Total	$209.83	$170.20	$144.16	$113.57	$353.99	$283.77

Note: Man labor is charged at the rate of 40¢ per hour and horse labor at 13¢ per hour.
*Includes such items as hallocks, crates, carriers, gas, oil, repairs, fruit hauling, and other miscellaneous expenses.
†Heavier first year owing to small acreage irrigated.

Naturally the cost per acre the first year for both irrigated and non-irrigated berries is considerably higher than it is during the second year of growth. This is due chiefly to the expense of those initial items which are usually required but once during the life of a berry crop, such as preparing the land for the crop, the purchase of plants, the setting of plants, and the purchase of trellis material. In the aggregate these items for red raspberries cost $124 more per acre the first year of growth than they did during the second year. On the other hand, the items of pruning and training canes, cultivating, cover-cropping, irrigating, fertilizing, and trellising, cost more the second year than the first year when the plants were set out.

The items of irrigation, power, interest, and depreciation were chiefly responsible for the difference in cost of establishing irrigated and non-irrigated red raspberries. The totals of all other items of cost remained about the same, inasmuch as both groups were treated alike.

Cost, yield, and income per year. Carrying the berries through five years of growth cost about one-third more for the irrigated plantings than for the non-irrigated plantings. The greater income from the irrigated crop, however, justified this additional cost (Table VII).

While the total five-year cost was $328.51 per acre higher for the irrigated than for the non-irrigated crop, the total receipts available to pay these costs were $613.35 per acre larger from the irrigated than from the non-irrigated crop.

The cost per acre of the irrigated berries during each year of bearing age was higher than it was from the non-irrigated berries, but the heavier production from the irrigated plants each year more than repaid the additional cost incident to irrigation. The average production from the irrigated crops for the three bearing years was 58 percent greater than that obtained from the crops grown without the use of irrigation water.

TABLE VII. TOTAL COST, YIELD, INCOME, AND PROFIT PER ACRE FOR FIRST FIVE YEARS OF GROWTH
Irrigated and Non-irrigated Red Raspberries

Item	Cost of establishing		Three bearing years						Yearly average for three bearing years		Total for five years	
	1926 and 1927		1928		1929		1930					
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Cost per acre (*dollars*)*	353.99	283.77	299.03	222.17	356.98	256.77	354.78	273.56	336.93	250.83	1364.78	1036.27
Yield per acre (*pounds*)	.....	.....	6,218	4,168	8,394	4,447	6,540	4,742	7,051	4,452	21,152	13,357
Cost per pound (*dollars*)	.....	.....	.048	.053	.042	.058	.054	.058	.048†	.057†	.....	.....
Gross income per acre (*dollars*)‡	.....	.....	466.35	312.60	671.52	355.76	523.20	379.36	553.69	349.24	1661.07	1047.72
Net income per acre (*dollars*)	.....	.....	167.32	90.43	314.54	98.99	168.42	105.80	216.76	98.41	296.29	11.45

*For itemized cost per acre see Table XXI, page 46.
†Weighted average cost, each year's cost weighted according to yield.
‡Price received per pound: 1928, 7.5¢; 1929, 8¢; 1930, 8¢.

Profit or loss per acre for first five years of growth. The net income obtained from the irrigated red raspberries during the three-year bearing period was more than double that received from the non-irrigated fruit (Figure 5).

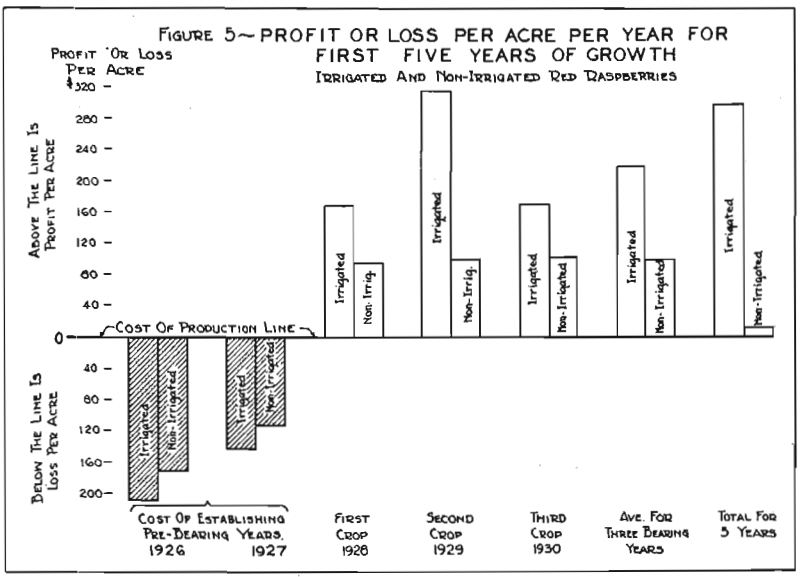

Figure 5.

The net profit per acre in the first year of bearing was 85 percent higher from the irrigated than from the non-irrigated plants. In the second year the net profit was 218 percent higher; the third year it was 59 percent higher, and the average yearly net return for the three bearing years was 120 percent higher than it was from the non-irrigated fruit.

If the cost of establishing the crop during the first two years of growth is added to all costs of production for the three succeeding years and this total is deducted from the gross receipts for the five-year period, the net return from the irrigated berries for the five years of growth will be found to be $284.84 per acre higher than it was from the non-irrigated crop.

Comparative size of berry. The irrigated berries maintained a larger size by an average of 7 percent than did the fruit from the non-irrigated plants. The size of the berries from all plots decreased as the season advanced (Figure 6).

The difference in size of berries produced from both the irrigated and the non-irrigated plantings remained fairly uniform during the entire picking season. The greatest difference in size of berries was during the fourth picking when the individual irrigated fruits outweighed the non-irrigated by 21 percent. The narrowest margin in size was during the eighth picking, when the irrigated berries were only 12 percent larger than the non-irrigated fruits.

The results of the 1928 size test show that the berries on canes that were more than six feet in length dropped rapidly in size, even under irrigation. The size was maintained very well up to six feet of cane growth. The berries on the first foot of the canes were largest in size, and those on the upper two feet of the eight-foot canes were much smaller, dropping in weight 38 percent and 46 percent respectively for the seventh and eighth feet of the cane. Neither the size nor the yield on the first five feet of cane

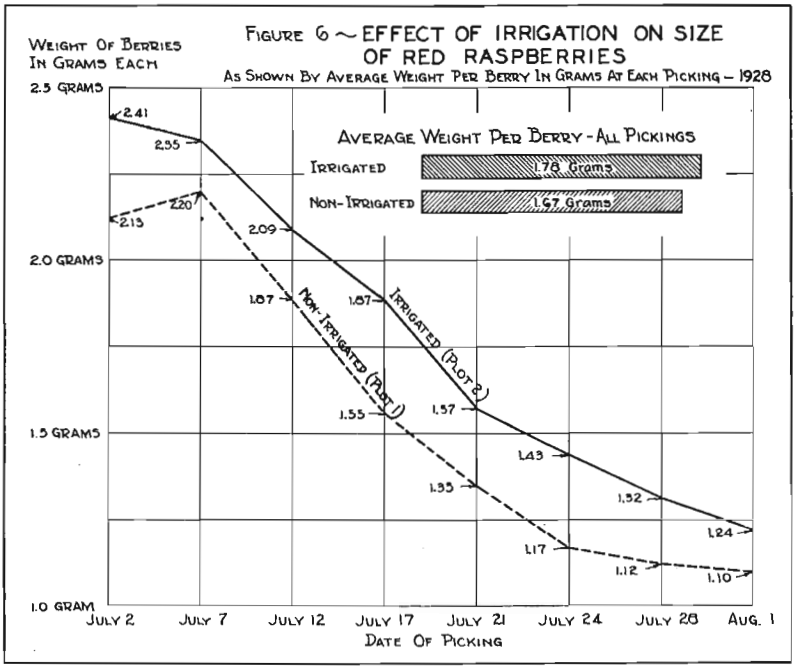

Figure 6.

length was reduced by allowing the next three feet to remain on the cane. The berries produced on the upper three feet of cane length were simply an addition to the crop without affecting the remainder of the production (Figure 7). These results are for one year only and cannot be taken as final.

Effect of irrigation on cane growth and hardiness of plant. There was very little increase in the cane growth of red raspberries, owing to irrigation under the conditions of this experiment, but there is some difference in the amount of cane growth which a plant can support during the bearing season. Lengths of cane which the plant can support under irrigation have been under observation, but the optimum length has not yet been determined as results have not been consistent.

The cane growth of all plots was so great that it was found to be impossible to grow a cover-crop and it was necessary to maintain humus and general fertility by other methods.

Less secondary bloom was produced by irrigated plants than by those not irrigated, owing to the fact that vegetative growth on the irrigated canes continued later in the summer. This may be considered as an advantage of irrigation inasmuch as the late bloom consumes plant energy which should be stored in the plant for use in producing the following crop.

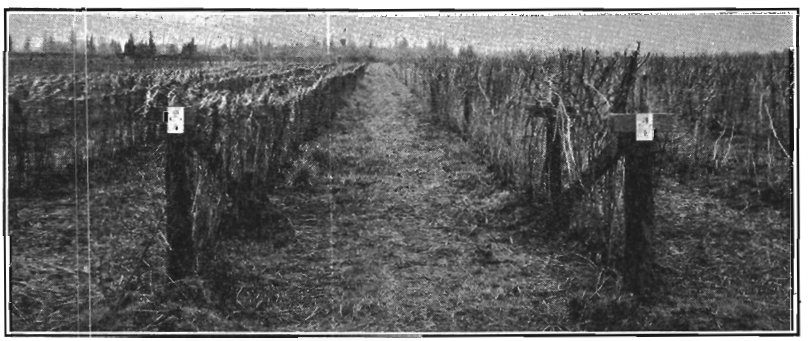

Figure 7. *Left:* The method of training and pruning red raspberries whereby the extra yield of early berries was produced on the upper part of the long canes. *Right:* The short method of pruning red raspberries.

No difference has been observed between irrigated and non-irrigated red raspberry plants as to resistance to disease or winter injury. Rust is the only disease which has been observed to any appreciable extent and the economic loss because of it has been very small. Winter injury, although not affected by irrigation, has been the most important single factor in reducing the yield.

Effect of irrigation on time of ripening. Irrigation does not retard ripening. In fact two pickings were made on the irrigated plots with long canes before any of the berries on the non-irrigated plots were ripe.

On the irrigated plots it has been profitable to leave a greater length of cane. Not only did the longer canes yield more fruit but it was from the tips of these longer canes that the earlier berries were obtained (Figure 7). These earlier berries sold at a premium as fresh fruit over the price received for the bulk of the crop which was sold to the cannery.

The peak of the picking season of the irrigated plots came one week earlier than for that of the non-irrigated plots. The yields held up somewhat better until the end of the season. Not only was the production of fruit greater on the irrigated plots at the time of each picking, with one exception, but the percentage of the crop harvested by the end of each picking date was larger than it was for the dry plots. This was the case until the eighth picking, after which time the percentage of the total crop harvested was about the same for both groups.

Effect of irrigation on canning quality. The quality of the canner berries from the irrigated plots was fully as good as that from the non-irrigated plots. The color as a rule was more attractive and the flavor more pleasing in the irrigated berries. The berries from the irrigated plots showed a shrinkage of 24.8 percent when canned, as compared with 22 percent for

TABLE VIII. THE INFLUENCE OF IRRIGATION ON THE CANNING QUALITY OF CUTHBERT RED RASPBERRIES

1929

Canned July 9. Examined February 15.

Item	Dry weight of fresh fruit	No. of fruits in No. 2 can	Weight of fresh fruit (Grams per can)	Weight of fruit after canning (Grams per can)	Shrinkage	Concentration of sirup before canning (Balling)	Concentration of sirup after canning (Balling)
	%		*Grams*	*Grams*	%	%	%
Non-irrigated	10.56	144.2	350	273	22.0	60	35.1
Irrigated	10.69	118.6	350	263	24.8	60	34.8

the non-irrigated berries (Table VIII). This difference is not great enough to be significant. The concentration of the sirup of the two lots of berries was practically the same. The dry matter in the irrigated berries was 10.69 percent as compared to 10.56 percent for the non-irrigated. The variation between different cans of fruit of each lot was greater than the difference between the plots.

LOGANBERRIES

In March, 1927, loganberry plants were set in rows 9 feet apart with the plants 9 feet apart in the row. The vines were trellised on two wires, one above the other.

Cost of establishing. Usually two years are required to establish a loganberry planting and bring it into commercial production. In this test, however, the yield of the crop during the second year of growth was of sufficient size to consider the planting fully established at the end of one year. The yield the second year was 1,186 pounds per acre from the dry plots and 3,436 pounds per acre from the irrigated plots.

The cost the first year of growth was 18 percent higher for the irrigated crop than it was for the non-irrigated crop (Table IX).

TABLE IX. COST PER ACRE OF ESTABLISHING IRRIGATED AND NON-IRRIGATED LOGANBERRIES, 1927*

Item	Irrigated	Non-irrigated
Preparing land	$27.27	$27.27
Plants (538 per acre)	5.50	5.50
Setting plants	11.77	11.77
Cultivating	22.34	22.32
Trellising	61.28	61.27
Staking	3.27	3.27
Irrigating (labor only)	12.43	.....
Power cost for irrigating	4.20	.....
Cover-cropping	1.12	1.09
Cover-crop seed	1.75	1.75
Land rental	15.00	15.00
Supplies and repairs†	16.36	16.36
Interest (on equipment)	6.50	.40
Depreciation (on equipment)	7.71	.90
Total	$196.50	$166.90

Note: Man labor is charged at the rate of 40¢ per hour and horse labor at 13¢ per hour.

*One year only required in this test to establish loganberry planting.

†Includes such items as hallocks, crates, carriers, gas, oil, repairs, fruit hauling, and other miscellaneous expenses.

The cost chargeable primarily to irrigation and pumping and the larger amounts required for interest and depreciation, owing to irrigation investment, are responsible for this difference in cost during the first year of the life of the planting.

Cost, yield, and income per year. The production from the irrigated berries the second and third years of growth was double that obtained from the non-irrigated crop (Table X).

TABLE X. TOTAL COST, YIELD, INCOME, AND PROFIT PER ACRE FOR FIRST FOUR YEARS OF GROWTH
Irrigated and Non-irrigated
Loganberries

Item	Cost of establishing 1927		Two bearing years 1928		1929		Yearly average for two bearing years		Frost. No crop. 1930		Total for four years	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Cost per acre (*dollars*)*	196.50	166.90	224.44	153.20	360.15	224.93	292.29	189.06	152.97	122.90	934.06	667.93
Yield per acre (*pounds*)			3,436	1,186	10,666	5,831	7,051	3,508			14,102	7,017
Cost per pound (*dollars*)			.0653	.129	.034	.038	.041†	.054†				
Gross income per acre (*dollars*)‡			171.80	59.30	533.30	291.55	352.55	175.42			705.10	350.85
Net income per acre (*dollars*)			−52.64	−93.90	173.15	66.62	60.26	−13.64	−152.97	−122.90	−228.96	−317.08

*For itemized cost per acre see Table XXII, page 47.
†Weighted average cost, each year's cost weighted according to yield.
‡Price received per pound: 1928, 5¢; 1929, 5¢.

TABLE XI. THE INFLUENCE OF IRRIGATION ON THE CANNING QUALITY OF LOGANBERRIES
1929
Fruit canned July 9. Examined February 15.

Item	Dry weight of fresh fruit	No. of fruits in No. 2 cans	Weight of fresh fruit (Grams per can)	Weight fruit after canning (Grams per can)	Shrinkage	Concentration of sirup before canning (Balling)	Concentration of sirup after canning (Balling)
	%		*Grams*	*Grams*	%	%	%
Non-irrigated	15.2	99.8	350	278.0	20.6	70	40.7
Irrigated	14.8	72.0	350	268.0	23.4	70	41.2

The fourth year the loganberry crop was killed by a severe freeze resulting in the harvesting of only two crops during the four years of growth. This loss of the third crop without comparable reduction in cost resulted in a deficit per acre at the end of four years for both irrigated and non-irrigated berries. The loss from the non-irrigated fruit, however, was one-third more than it was from the plants that received irrigation. The total cost from time of planting to four years of age was 40 percent higher for the irrigated fruit than it was for the non-irrigated fruit, but the gross income available to pay this higher cost was double that available from the non-irrigated berries.

Profit or loss per acre for first four years of growth. While the irrigated berries made an average annual profit of $60.26 per acre for the two years of bearing, the non-irrigated fruit suffered a loss of $13.64 (Figure 8).

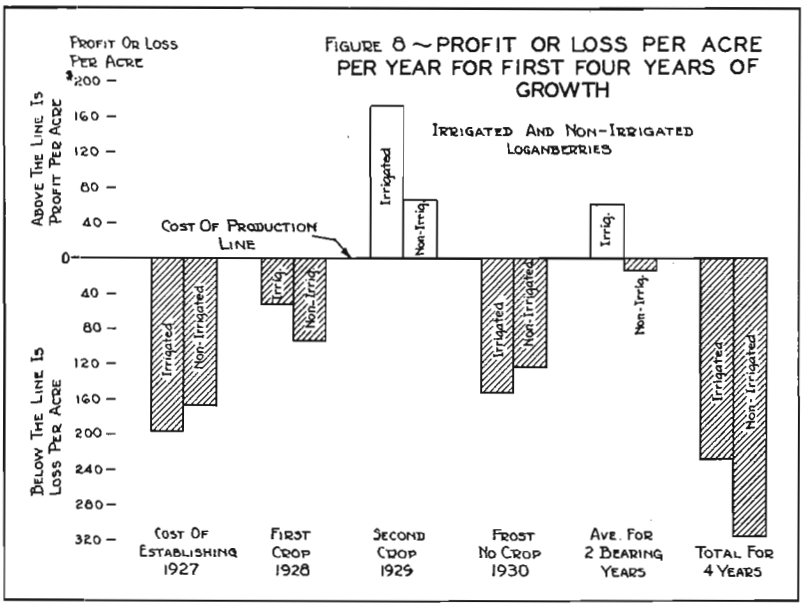

Figure 8.

Even though both irrigated and non-irrigated plantings showed a loss at the end of four years of growth, owing to winter killing the fourth year, the feasibility and economic advantage of the irrigation of this fruit is clearly indicated. Frost sufficient to destroy the crop is not a common occurrence in the Willamette Valley.

Comparative size of berry. The berries from the irrigated plots in 1929 were more than one-third larger than those grown without irrigation (Figure 9).

The maximum difference in size between the irrigated and the non-irrigated fruit occurred at the time of the second picking, when the irrigated fruit averaged 63 percent heavier than the dry-grown fruit. The

smallest difference in size was during the seventh picking, when the irrigated berries were only one-fourth larger than the non-irrigated berries.

Effect of irrigation on cane growth. Cane growth is greatly increased by the irrigation of loganberry plants. In the tests conducted, irrigation kept the canes growing long after the usual season for growth had passed. Such vigorous growth resulted in the production of a large number of laterals which was particularly noticeable in 1928, but to a lesser degree in 1929, when a heavy crop was formed. In 1930, after loss of the crop by winter injury, the irrigated loganberry plants developed 15 to 35 canes each, with many laterals to the cane.

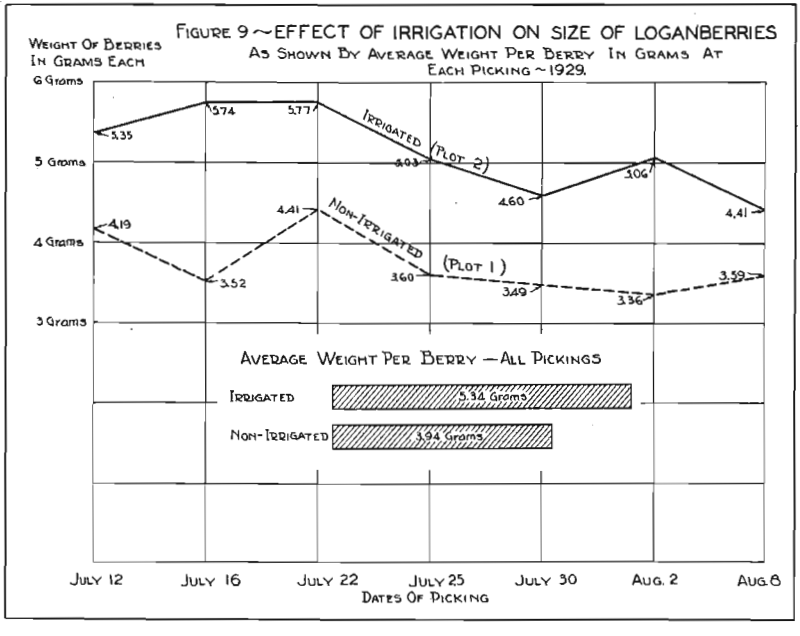

Figure 9.

In 1929 all of the canes on the dry plot were pruned to 6 feet in length in an effort to obtain the maximum yield of No. 1 berries. One irrigated plot was pruned in the same manner. This irrigated plot out-yielded the non-irrigated plot 13 percent. The dry plots produced the greatest number of berries, but the average size per berry was much smaller than those from the irrigated plots. A smaller number of buds was found on the irrigated canes 6 feet in length than on the canes of similar length produced without irrigation. Apparently the increased vigor and growth resulting from irrigation caused greater distance between the nodes.

A comparison of the yield of fruit and the size of berries produced under irrigation from loganberry hills having different cane lengths, is shown in Figure 10.

The canes in the four irrigated plots were so pruned that the length averaged 36 feet, 64 feet, 100 feet, and 120 feet per hill respectively. This aggregate cane length per hill was obtained by leaving 6 canes 6 feet long in one plot, 8 canes 8 feet long in another, 10 canes 10 feet long in another, and 10 canes 12 feet long in a fourth plot.

The longer canes produced the larger crop but the size of the berries declined as the length of the canes increased. In fact, the crop produced

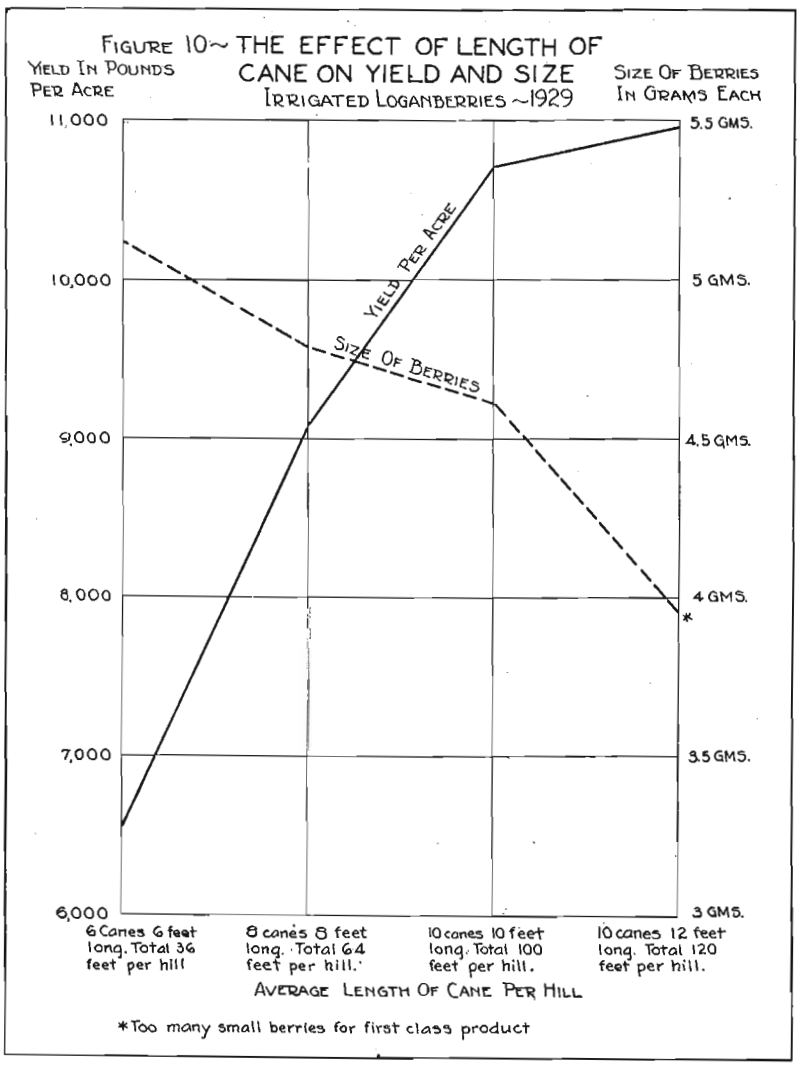

Figure 10.

from the hills having 120 feet of cane growth was of inferior quality, owing to the number of under-size berries.

The optimum length of canes for loganberries grown under irrigation was found to be 100 feet per hill or 10 canes 10 feet long. That length of

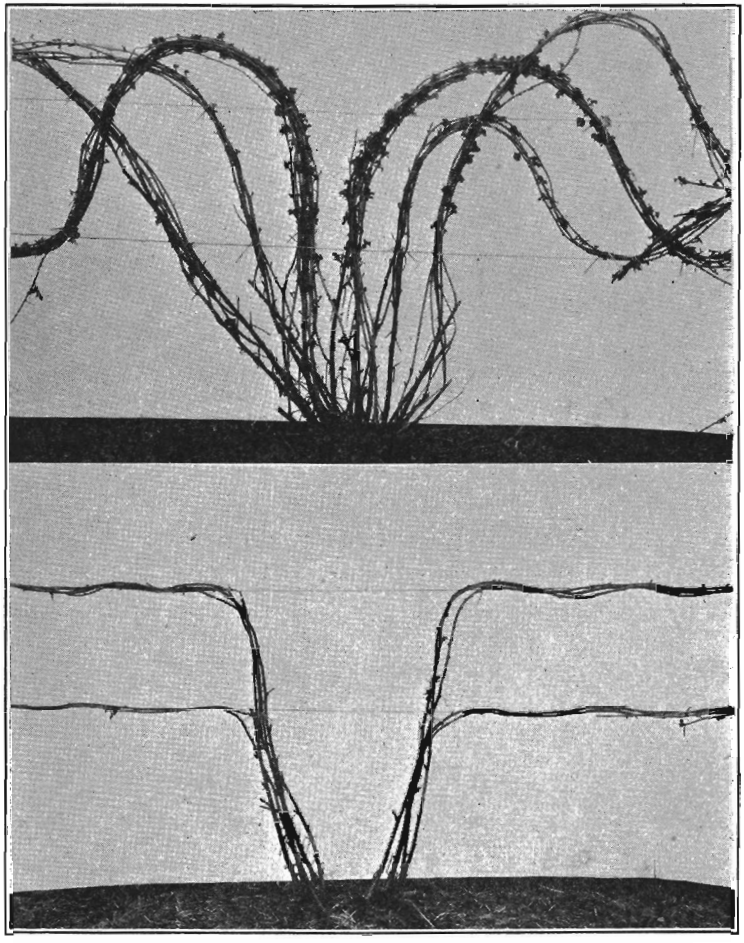

Figure 11. Extremes in length of loganberry cane growth. *Upper:* Too much cane growth gives a large tonnage but small berries. *Lower:* Too little cane growth gives small tonnage of large berries.

cane growth produced in 1929 at least, a maximum crop of marketable berries. Figure 11 illustrates the difference between the extremes in length of cane growth left in this pruning.

At the time of this test the loganberry planting was only two years of age and not fully mature. Furthermore, the data cover the crop of but one

year, consequently the figures cannot be considered as conclusive. The elimination of the 1930 crop due to winter killing prevented the continuation of the test during that season. Further tests will be conducted with succeeding crops.

Effect of irrigation on time of ripening. Irrigation slightly retards the date of ripening of loganberries (Figure 12).

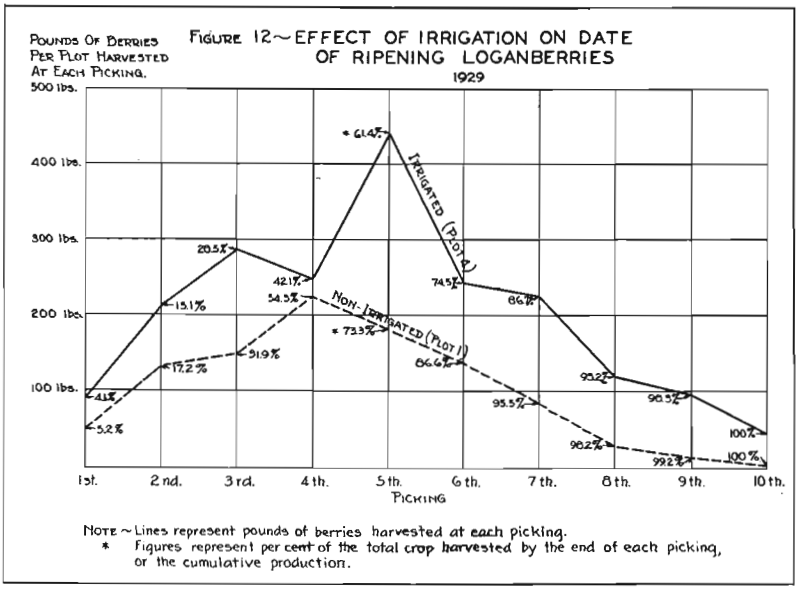

Figure 12.

A larger percentage of the total production was harvested from the dry plot by the end of each picking date than was gathered from the irrigated plots.

Effect of irrigation on canning quality. The canning quality of loganberries was improved by irrigation (Table XI, page 26). The flavor of the irrigated loganberry was milder than that of the non-irrigated berry while the color tended to be brighter. There was very little difference in dry weight of the two kinds of fruit.

BLACK RASPBERRIES

The black raspberry plants were handled in a similar manner to that of the red raspberries and the Evergreen blackberries. The ground was plowed and leveled in March, 1926, and plants of the Plum Farmer variety were set in April in rows 9 feet apart and 4 feet apart in the row. The trellis consisted of two parallel wires strung on cross-arms 24 inches above the ground.

Cost of establishing. To establish irrigated black raspberries and carry them to two years of age cost $72.92 per acre more than it did for the non-irrigated crop (Table XII).

As in the case of the other bramble fruits, the cause for this increased cost was due primarily to the cost of the items of irrigation, pumping power, interest, and depreciation.

TABLE XII. COST PER ACRE OF ESTABLISHING IRRIGATED AND NON-IRRIGATED BLACK RASPBERRIES

Item	1926		1927		Total cost to bearing age	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Preparation of land	$ 27.27	$ 27.27	.....	.....	$ 27.27	$ 27.27
Plants (1,210 per acre)	18.69	18.68	.....	.....	18.69	18.68
Setting plants	26.86	26.86	$ 3.82	$ 3.82	30.68	30.68
Cultivating	14.97	14.95	16.56	16.55	31.53	31.50
Trellis	52.41	52.36	.....	.....	52.41	52.36
Trellising	.....	.....	12.68	12.69	12.68	12.69
Irrigating (labor only)	12.91	.....	14.02	.....	26.93	.....
Power cost for irrigating	5.24	.....	4.20	.....	9.44	.....
Pruning and training	.....	.....	5.32	5.32	5.32	5.32
Supplies and repairs*	10.91	10.91	16.36	16.36	27.27	27.27
Miscellaneous labor	3.05	3.05	.....	.....	3.05	3.05
Land rental	15.00	15.00	15.00	15.00	30.00	30.00
Interest (on equipment)	11.91†	.45	6.50	.40	18.41	.85
Depreciation (on equipment)	13.00†	.90	7.71	.90	20.71	1.80
	$212.22	$170.43	$102.17	$71.04	$314.39	$241.47

Note: Man labor is charged at the rate of 40¢ per hour and horse labor at 13¢ per hour.
*Includes such items as hallocks, crates, carriers, gas, oil, repairs, fruit hauling, and other miscellaneous expenses.
†Heavier the first year owing to small acreage irrigated.

At the end of two years from date of planting a total of $314.39 per acre had been expended on the irrigated plots and $241.47 per acre had been put into the non-irrigated plots. This represents the cost of establishing the crop and bringing it to the age of commercial production.

Cost, yield, and income per year. Although it cost 45 percent more for the irrigated black raspberries during the three bearing years 1928, 1929, and 1930, than it did for the non-irrigated fruit, the gross returns from the irrigated production brought 115 percent more money with which to meet these obligations. These percentages indicate a distinct advantage in the irrigation of this crop (Table XIII).

On the basis of the entire five-year period of growth, it was found that the total cost of growing the irrigated crop was more than one-third higher than it was for the non-irrigated; the yield of the irrigated crop was more than twice as large, and the gross return from sale thereof was more than double that obtained from the non-irrigated crop. The higher returns from the irrigated crop for each year of production indicate the economic advantage of irrigating the black raspberry crop.

Profit or loss per acre for first five years of growth. Notwithstanding the fact that this experiment has shown that irrigation of black raspberries will increase the yield and the returns, the results of the five-year test indicate that both the irrigated and the non-irrigated crops sustained a severe loss for the period. The only exception was that of the irrigated crop of

TABLE XIII. TOTAL COST, YIELD, INCOME, AND PROFIT PER ACRE FOR FIRST FIVE YEARS OF GROWTH
Irrigated and Non-irrigated Black Raspberries

Item	Cost of establishing		Three bearing years						Yearly average for three bearing years		Total for five years	
	1926-1927		1928		1929		1930					
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Cost per acre (*dollars*)*	314.39	241.47	240.03	172.07	258.75	193.38	226.42	134.79	241.73	166.75	1,039.59	741.71
Yield per acre (*pounds*)	.....	.....	2,759	1,172	3,843	2,448	2,523	714	3,042	1,445	9,125	4,334
Cost per pound (*dollars*)	.....	.....	.087	.146	.067	.08	.089	.188	.08†	.115†	.....	.....
Gross income per acre (*dollars*)‡	.....	.....	220.72	93.76	269.01	171.36	201.84	57.12	230.52	107.42	691.57	322.24
Net income per acre (*dollars*)	.....	.....	−19.31	−78.31	10.26	−22.02	−24.58	−77.67	−11.21	−59.33	−348.02	−419.47

*For itemized cost per acre see Table XXIII, page 48.
†Weighted average cost, each year's cost weighted according to yield.
‡Price received per pound: 1928, 8¢; 1929, 7¢; 1930, 8¢.

1929, which produced a profit of $10.26 per acre, while the non-irrigated crop sustained a loss of $22.02 (Figure 13).

Despite the reduction of 40 percent in the weighted average cost per pound and the increase of 115 percent in the gross income per acre owing to irrigation, both the watered and the dry plots sustained a material loss. The loss from the irrigated crop, however, was $48.12 per acre less than it was from the crop receiving no irrigation.

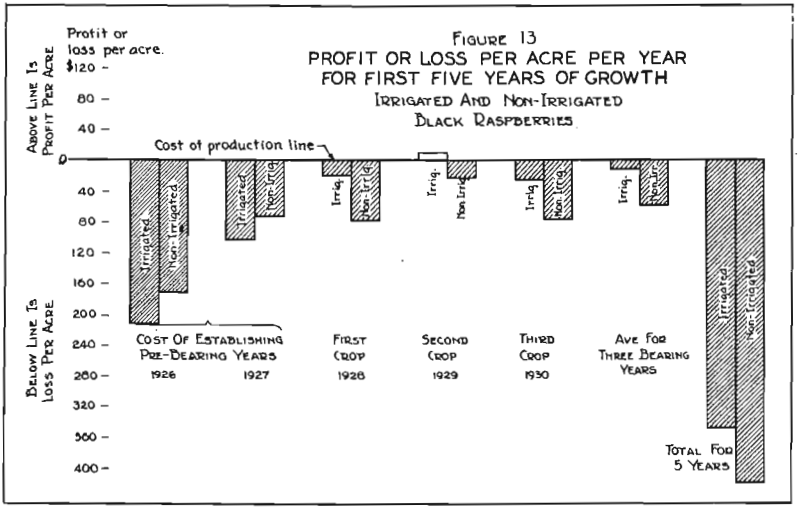

Figure 13.

Notwithstanding the fact that there appears to be a fair market demand for dried black raspberries, as reported in Oregon Agricultural Experiment Station Bulletin 274, under the conditions of this experiment the production of this fruit either with or without irrigation must be considered as unprofitable. The price was good but the yield was too low.

Comparative size of berry. The black raspberries grown under irrigation were, on the average, nearly one-fourth larger in size than those berries produced from the non-irrigated plots (Figure 14). Throughout the harvesting season the irrigated berries were uniformly larger in size than the fruit grown without irrigation.

Effect of irrigation on cane growth. Cane growth on black raspberries is greatly increased by irrigation. By the middle of August of each year the lateral growth was so thick in the irrigated plots that it was impossible to cultivate or work among the canes. This resulted in shading the ground so completely that only meager cover-crops could be grown.

To determine the effect of length of canes on the yield and size of berries when grown under irrigation, varying lengths of canes were left on the different irrigated plots. Plot 2 had 60 buds; Plot 3, 80 buds; Plot 4, 144 buds; and Plot 5, more than 300 buds, respectively, per hill.

The results of this test are given in Figure 15.

As indicated in Plot 4, black raspberry plants carrying 144 buds per hill proved to be the most satisfactory in the 1928 crop (Figure 15). When the number of buds per hill was increased to 300 or more (Plot 5), the yield of the fruit was only slightly increased, but the size of the berries was greatly diminished. In fact, many of the berries harvested from this plot were so small and seedy that they were useful only for drying purposes

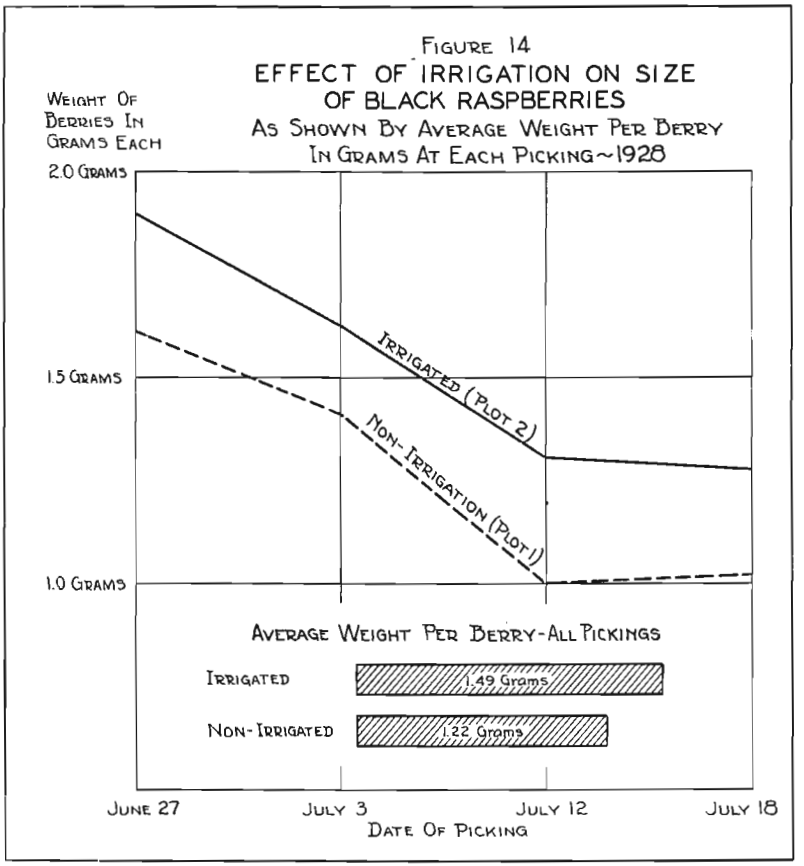

Figure 14.

or for the dye trade. The same comparative results were obtained in 1929 and 1930. In 1930 the best yields were from hills of 6 canes, with 6 laterals and 6 buds, or 216 buds to a hill.

Effect of irrigation on vigor of black raspberry plants. Plant vigor is often claimed as a preventive against disease, but the increased cane growth in the black raspberry plants did not carry with it an increased immunity toward disease. Verticillium is very destructive to black raspberry plants in this state. By the end of 1930, in spite of irrigation and the increased growth of the healthy bushes 6.5 percent of the entire planting

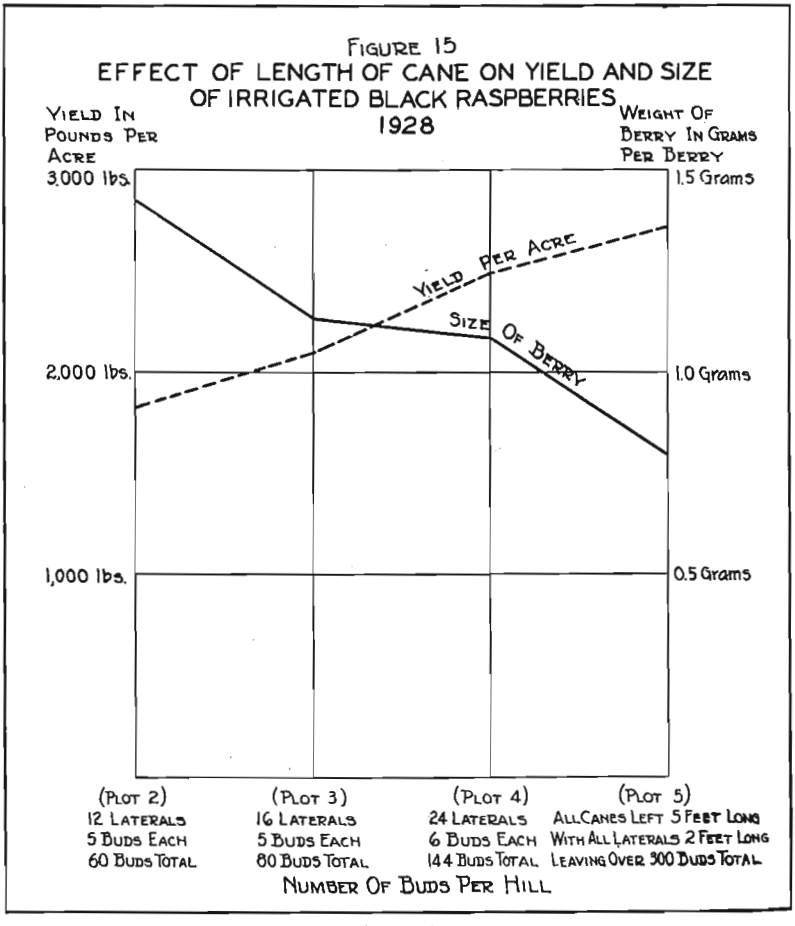

Figure 15.

had been destroyed by disease or from other causes, and the loss was increasing. In 1929 the loss was two and one-half times as great in the irrigated plots as it was in the dry plots. In 1930 the loss was uniform throughout the irrigated and the non-irrigated plantings.

Effect of irrigation on canning quality. Irrigation does not materially affect the quality of the canned black raspberries (Table XIV). When canned, the irrigated berries had a tendency to turn a purplish color rather than to maintain the usual jet black color of black raspberries.

TABLE XIV. THE INFLUENCE OF IRRIGATION ON THE CANNING QUALITY OF PLUM FARMER BLACK RASPBERRIES

1929

Fruit canned July 9. Examined February 14

Item	Dry weight of fresh fruit	No. of fruits in No. 2 can	Weight of fresh fruit (grams per can)	Weight of fruit after canning (Grams per can)	Shrinkage	Concentration of sirup before canning (Balling)	Concentration of sirup after canning (Balling)
	Grams		*Grams*	*Grams*	%	%	%
Not irrigated	20.6	263.0	350	313.3	10.6	60	37.0
Irrigated	18.7	195.4	350	313.0	10.6	60	36.8

STRAWBERRIES

At the beginning of this test in April, 1926, strawberries of the varieties of Marshall, Gold Dollar, and Ettersburg 121 were set in rows 3 feet apart with the plants 3 feet apart in the row. At the end of the first season the Marshall and Gold Dollar varieties, which had not been irrigated, had died out, owing to dry-weather conditions, and were plowed up in the summer of 1927. This same land was then replanted to the Marshall and Ettersburg 121 varieties in March, 1928. The Gold Dollar variety was not replanted as it was found to be but very little earlier than the Marshall and its fruit was always difficult to dispose of when the Marshall variety began to ripen.

For the reasons stated above the cost of establishing the strawberry plantings could not be accurately determined. Data on this operation covering actual farm conditions are available, however, in Oregon Agricultural Experiment Station Bulletin 245, Cost and Practices in Strawberry Production in the Willamette Valley.

The Marshall used in this test is the same variety as that commonly called the "Oregon" in many sections of the state. This variety has also been grown extensively in California under irrigation. This report contains the results obtained in the irrigation of the Marshall and Ettersburg 121 varieties which were planted in 1928.

Cost, yield, and income per year. Irrigating the Marshall strawberries brought an increased average annual profit of $94.81 per acre for the two bearing years 1929 and 1930. Irrigating the Ettersburg 121 variety, however, decreased the net income $27.81 per acre. Under the conditions of this experiment, irrigation is profitable with the Marshall variety, but not with the Ettersburg 121 (Table XV).

Irrigation increased the yield of the Marshall variety 69 percent for the first crop and 117 percent for the second. The average yield for the two bearing years was 82 percent greater from the irrigated Marshall strawberries than it was from the non-irrigated plants.

Irrigation increased the average net income of the Marshall variety 110 percent and decreased the net income of the Ettersburg 121 variety 50 percent.

Just why one variety of strawberries should respond favorably to irrigation and another variety respond unfavorably is not known. The Ettersburg 121 strawberry, unlike other commercial varieties, grows heavy lateral roots which may supply sufficient moisture to mature a crop whether irrigated or not. Irrigation appeared to be responsible for a slight increase in yield of the Ettersburg 121 variety in 1930, the second year of bearing, but the non-irrigated plots out-yielded the irrigated area during the first bearing year.

Effect of irrigation on time of ripening. Irrigation tended to delay the ripening of the Marshall strawberries but hastened the ripening date of the Ettersburg 121 variety (Table XVI). At each picking date of the Marshall variety a larger percentage of the total non-irrigated crop was harvested than of the irrigated fruit, indicating that the irrigated berries were ripening more slowly than the dry-grown fruit. More berries were

TABLE XV. TOTAL COST, YIELD, INCOME, AND PROFIT PER ACRE
Irrigated and Non-irrigated Marshall and Ettersburg 121 strawberries for 1929 and 1930

Item	1929				1930				Yearly average for two bearing years			
	Marshall		Ettersburg 121		Marshall		Ettersburg 121		Marshall		Ettersburg 121	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Cost per acre (*dollars*)	314.63	190.39	167.38	147.21	167.63	94.84	87.41	69.74	241.13	142.62	127.40	108.48
Yield per acre (*pounds*)	10,565	6,239	3,872	4,276	5,274	2,435	1,361	1,211	7,919	4,337	2,616	2,743
Cost per pound (*dollars*)	.0297	.0305	.043	.0344	.0317	.0389	.0642	.0575	.0304*	.0328*	.0487*	.0395*
Gross income per acre (*dollars*)†	528.25	311.95	271.04	299.32	316.44	146.10	95.27	84.77	422.34	229.02	183.15	192.04
Net income per acre (*dollars*)	213.62	121.56	103.66	152.11	148.81	51.26	7.86	15.03	181.21	86.40	55.75	83.56

*Weighted average cost, each year's cost weighted according to yield.
†Prices received per pound: Marshall, 1929, 5¢; 1930, 6¢. Ettersburg 121, 1929, 7¢; 1930, 7¢.

TABLE XVI. PERCENTAGE OF THE TOTAL CROP OF STRAWBERRIES PICKED AT THE END OF EACH PICKING
Irrigated and Non-irrigated Marshall and Ettersburg 121 varieties
1930 crop

Variety and crop	First picking	Second picking	Third picking	Fourth picking	Fifth picking	Sixth picking	Seventh picking	Eighth picking	Ninth picking	Tenth picking	Eleventh picking	Twelfth picking	Thirteenth picking	Fourteenth picking
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Marshall Variety														
Irrigated crop	.3	1.6	4.9	7.1	12.7	23.3	31.4	48.7	65.1	74.1	83.1	90.3	95.5	100
Non-irrigated crop	1.0	2.9	9.8	14.2	14.2	30.8	42.4	66.7	76.6	76.6	89.5	94.3	97.2	100
Ettersburg 121 Variety														
Irrigated crop	41.2	65.7	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Non-irrigated crop	16.5	51.4	84.4	95.4	100	.....	.....	.....	.....	.....	.....	.....	.....	.....

harvested from the irrigated plot at each picking, however, than from the dry plots, except at the first picking date.

With the Ettersburg 121 variety the reverse condition was obtained. With this variety the irrigated fruit ripened more quickly than the non-irrigated fruit. Almost one-half of the total irrigated crop was harvested at the first picking. This increased to a total of two-thirds of the crop at the second picking, and the remainder of the production at the third picking date. The harvesting of the dry-grown Ettersburg 121 required five pickings, or two more pickings than was needed with the irrigated plants.

Summer planting of strawberries indicated possible with irrigation. Under irrigation it appears practicable to plant some varieties of strawberries in the summer after a spring-planted crop has been harvested from the land. The Marshall, the Ettersburg 121, and the Corvallis variety were planted August 1, 1928. The following season 6,034 pounds per acre of berries were harvested from the Corvallis, 2,191 pounds from the Marshall, and 378 pounds from the Ettersburg 121 variety. The Corvallis variety appears to be particularly suited to summer planting. In 1930 this variety bore at the rate of 10,463 pounds per acre, indicating that vigor had not been impaired, owing to bearing the first season, nine months from date of planting.

SUMMARY OF THE ECONOMIC RESULTS OF IRRIGATION

The economic results of the irrigation of small-fruit crops as indicated by comparative cost of establishing, cost per pound, yield, and profit or loss per acre, are summarized in the following tables.

Summary of cost of establishing. Table XVII presents a summary of the cost of establishing the different bramble fruit crops. The cost of the establishment of each kind of fruit crop was greater with irrigation than without. This additional cost for the irrigated crops ranged from 18 percent to 30 percent higher than that required for the dry plantings.

TABLE XVII. SUMMARY OF COST PER ACRE OF ESTABLISHING IRRIGATED AND NON-IRRIGATED BRAMBLE FRUIT CROPS

Name of crop	1926		1927		Total cost from planting to bearing age	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Red raspberries	209.83	170.20	144.16	113.57	353.99	283.77
Evergreen blackberries	180.81	141.29	119.81	93.68	300.62	234.97
Loganberries*	.....	.....	196.50	166.90	196.50	166.90
Black raspberries	212.22	170.43	102.17	71.04	314.39	241.47

*In this test only one year was required to establish loganberries (see text page 25).

Summary of per-pound cost of production. A summary of the average cost per pound of the different irrigated and non-irrigated small-fruit crops is given in Table XVIII. The average cost of growing each kind of irrigated fruit, with one exception, was less per pound than it was for the

berries grown without irrigation. The one exception to this condition was in the case of the Ettersburg 121 strawberries, which were produced more cheaply from the dry plots.

TABLE XVIII. SUMMARY OF WEIGHTED AVERAGE COST OF PRODUCTION PER POUND IRRIGATED AND NON-IRRIGATED SMALL FRUITS
1928, 1929, 1930

Name of crop	Weighted average cost per pound for bearing years	
	Irrigated	Non-irrigated
	Cents	*Cents*
Red raspberries (three years)	4.8	5.7
Evergreen blackberries (three years)	3.3	3.9
Loganberries (two years)	4.1	5.4
Black raspberries (three years)	8.0	11.5
Marshall strawberries (two years)	3.0	3.3
Ettersburg 121 strawberries (two years)	4.8	3.9

Summary of yields. The summary of the yield per acre of the irrigated and the non-irrigated small-fruit crops is presented in Table XIX. The yield of every kind of irrigated berries for each year of bearing, with the single exception of Ettersburg 121 strawberries in 1929, was larger than the crop produced without irrigation. This increase in yield ranged from 37.9 percent to 253.4 percent in the bramble fruits. With strawberries, irrigation resulted in a loss of 9.4 percent in yield for the Ettersburg 121 variety in 1929 and it was responsible for an increase of 116.6 percent in yield for the Marshall variety in 1930.

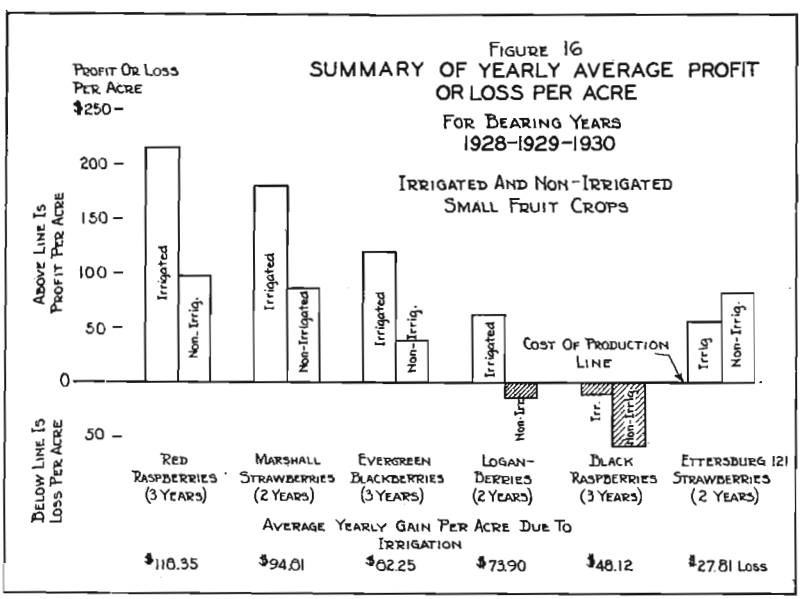

Figure 16.

TABLE XIX. SUMMARY OF YIELDS OF IRRIGATED AND NON-IRRIGATED SMALL-FRUIT CROPS

Pounds per acre
1928, 1929, 1930

Crop	1928			1929			1930			Total for bearing years		
	Irrigated	Non-irrigated	Percentage of increase from irrigation	Irrigated	Non-irrigated	Percentage of increase from irrigation	Irrigated	Non-irrigated	Percentage of increase from irrigation	Irrigated	Non-irrigated	Percentage of increase from irrigation
	Pounds	*Pounds*	%	*Pounds*	*Pounds*	%	*Pounds*	*Pounds*	%	*Pounds*	*Pounds*	%
Evergreen blackberries	4,445	2,377	87.0	11,079	5,286	109.6	17,133	11,606	47.6	32,657	19,269	69.5
Red raspberries	6,218	4,168	49.2	8,394	4,447	88.8	6,540	4,742	37.9	21,152	13,357	58.4
Black raspberries	2,759	1,172	135.4	3,843	2,448	57.0	2,523	714	253.4	9,125	4,334	110.5
Loganberries	3,436	1,186	189.7	10,666	5,831	82.9	*	*	.....	14,102	7,017	101.0
Marshall strawberries	.....	.....	.....	10,565	6,239	69.3	5,274	2,435	116.6	15,839	8,674	82.6
Average of percentage of increase, all berries	.....	.....	115.3	.....	.....	81.5	.....	.....	113.9	.....	.....	84.4

*1930 crop killed by freeze.
Note: Ettersburg 121 variety not included in this table because the experiment indicated irrigation reduced yield.

Summary of profit or loss per acre. Figure 16 presents a summary of the average net income received or loss sustained per acre in the production of the small-fruit crops with or without irrigation.

Producing small-fruit crops under irrigation proved to be more profitable than growing them without irrigation. The one exception to this condition was found to be the Ettersburg 121 strawberry, which was grown more profitably without the use of irrigation.

In the bramble fruits and with the Marshall strawberry the margin of profit credited to irrigation justifies the conclusion that the irrigation of these crops is a profitable practice. The profit advantage in irrigation is sufficiently great to offset possible inaccuracies in this test and the disadvantage of small-plot experiments.

Appendix

SUPPLEMENTARY TABLES SHOWING DETAILED COST OF PRODUCTION

Picking the heavier crops of the irrigated berries is responsible for from 45 percent to 63 percent of the difference in cost per acre of producing the various kinds of fruit. From 19 percent to 24 percent of the difference in cost is represented by irrigation expense, and from 12 percent to 18 percent is caused by interest and depreciation due to the heavier investment in the irrigated plantings.

Throughout this study man labor is charged at the rate of 40¢ per hour and horse labor at 13¢ per hour.

The variation in cost of power for pumping irrigation water as indicated in Tables XX to XXIII was caused by (1) the different methods used by the Electric Power Company in the application of the rate schedule. During one season the rates applying to each block of energy were applied on a monthly basis, whereas during another season these rates were applied on the basis of the total season's use, and (2) the irrigation of a different number of acres each year.

Included in supplies and repairs are such items as hallocks, crates, carriers, gas, oil, equipment repairs, and other miscellaneous expenses.

Growers of small-fruit crops and readers of this Bulletin should understand that the cost-of-production figures presented herein refer only to the actual cost of growing these crops under Experiment Station conditions. In all probability these costs, both for irrigated and non-irrigated berries, would be less under ordinary farm conditions. Naturally, therefore, the cost figures as given cannot be used with finality as representing the *general* cost of producing these fruits under practical farming methods in the Willamette Valley as a whole. It should be clear, however, that the economic advantage of irrigating berries, the increased yield and profits gained thereby, as presented herein, are applicable to the entire Willamette Valley wherever suitable soils and irrigation water supply are available.

The major differences in cost of producing irrigated and non-irrigated berries are indicated in Tables XX to XXIII.

TABLE XX. ITEMIZED COST OF PRODUCING IRRIGATED AND NON-IRRIGATED EVERGREEN BLACKBERRIES ON EXPERIMENT STATION FARM
1928, 1929, 1930

Item	Cost per acre					
	1928		1929		1930	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Man and horse labor						
Pruning and training—man labor	$ 55.45	$ 55.45	$ 95.50	$ 91.09	$ 64.09	$ 47.95
Cultivating—man labor	20.36	20.36	25.86	21.64	21.83	26.00
Cultivating—horse labor	6.33	6.32	4.70	4.82	4.86	5.32
Cultivating—tractor labor	.....	.....	.....	.....	1.02	1.00
Irrigating—man labor	18.18	.....	7.95	.....	20.23	.....
Irrigating—horse labor	1.18	.....	.74	.....	1.84	.....
Fertilizing—man labor	.....	.....	15.09	15.09	33.45	33.45
Fertilizing—horse labor	.....	.....	3.36	3.36	5.43	5.45
Fertilizing—truck labor	.....	.....	.82	.82	.....	.....
Cover-cropping—man labor	1.64	1.64	2.18	2.18	1.45	1.45
Cover-cropping—horse labor	.59	.59	.70	.73	.48	.45
Trellising—man labor	16.18	16.18	1.82	1.82	.....	.....
Picking—man labor	66.67	35.65	188.34	89.86	229.58	155.52
Materials						
Fertilizer	.....	.....	4.83	4.82	9.09	9.09
Cover-crop seed	1.75	1.75	1.75	1.75	1.48	1.48
Supplies and repairs	14.55	14.55	6.27	6.27	15.00	15.00
General						
Land rental	15.00	15.00	15.00	15.00	15.00	15.00
Power cost for pumping	5.00	.....	2.78	.....	2.20	.....
Interest and depreciation						
Interest—irrigation and farm equipment	7.30	.35	6.05	.30	6.20	.25
Depreciation—irrigation and farm equipment	8.32	.90	7.40	.90	8.00	.90
Total	$238.50	$168.74	$391.14	$260.45	$441.23	$318.31

TABLE XXI. ITEMIZED COST OF PRODUCING IRRIGATED AND NON-IRRIGATED RED RASPBERRIES ON THE EXPERIMENT STATION FARM
1928, 1929, 1930

Item	Cost per acre					
	1928		1929		1930	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Man and horse labor						
Pruning and training—man labor	$ 27.82	$ 27.82	$ 49.36	$ 27.09	$ 34.50	$ 32.36
Cultivating—man labor	43.45	43.45	28.82	28.14	20.97	24.32
Cultivating—horse labor	9.27	9.27	6.73	6.09	4.81	5.18
Cultivating—tractor labor	.....	.....	.....	.....	.....	5.45
Irrigating—man labor	14.32	.....	10.23	.....	17.04	.....
Irrigating—horse labor	2.07	.....	1.18	.....	2.07	.....
Fertilizing—man labor	14.30	14.27	22.27	21.59	15.28	15.30
Fertilizing—horse labor	8.86	8.86	1.48	1.00	4.14	4.12
Fertilizing—truck labor	.....	.....	6.51	6.00	1.91	1.91
Cover-cropping—man labor	1.45	1.45	2.27	1.82	1.45	1.45
Cover-cropping—horse labor	.48	.45	.74	.59	.92	.95
Picking—man labor	124.36	83.36	181.31	133.41	196.20	142.26
Materials						
Fertilizer	3.64	3.60	4.83	4.82	9.09	9.09
Cover-crop seed	1.75	1.75	1.75	1.75	.....	.....
Supplies and repairs	11.64	11.64	6.27	6.27	15.00	15.00
General						
Land rental	15.00	15.00	15.00	15.00	15.00	15.00
Power cost for pumping	5.00	.....	2.78	.....	2.20	.....
Miscellaneous	.....	.....	2.00	2.00	.....	.....
Interest and depreciation						
Interest—irrigation and farm equipment	7.30	.35	6.05	.30	6.20	.27
Depreciation—irrigation and farm equipment	8.32	.90	7.40	.90	8.00	.90
Total	$299.03	$222.17	$356.98	$256.77	$354.78	$273.56

TABLE XXII. ITEMIZED COST OF PRODUCING IRRIGATED AND NON-IRRIGATED LOGANBERRIES ON EXPERIMENT STATION FARM
1928, 1929, 1930

Item	Cost per acre					
	1928		1929		1930	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Man and horse labor						
Pruning and training—man labor	$ 33.27	$ 33.27	$ 81.22	$ 50.82	$ 34.68	$ 34.68
Cultivating—man labor	23.82	23.82	20.09	16.91	12.57	12.55
Cultivating—horse labor	7.03	7.05	4.65	3.45	3.16	3.18
Irrigating—man labor	16.36	.....	11.82	.....	13.64	.....
Irrigating—horse labor	1.77	.....	1.11	.....	1.18	.....
Fertilizing—man labor	.....	.....	24.18	24.18	21.27	21.27
Fertilizing—horse labor	.....	.....	2.77	2.77	.....	.....
Fertilizing—truck labor	.....	.....	5.18	5.19	8.05	8.05
Cover-cropping—man labor	1.45	1.45	2.18	2.18	1.45	1.45
Cover-cropping—horse labor	.48	.45	.70	.73	.....	.....
Trellising—man labor	36.80	36.82	.....	.....	.....	.....
Picking—man labor	51.54	17.79	160.00	87.46	.....	.....
Materials						
Fertilizer	.....	.....	6.27	6.27	9.09	9.09
Cover-crop seed	1.75	1.75	1.75	1.75	1.48	1.48
Supplies and repairs	14.55	14.55	5.00	5.00	15.00	15.00
General						
Land rental	15.00	15.00	15.00	15.00	15.00	15.00
Power cost for pumping	5.00	.....	2.78	.....	2.20	.....
Miscellaneous	.....	.....	2.00	2.00	.....	.....
Interest and depreciation						
Interest—irrigation and farm equipment	7.30	.35	6.05	.32	6.20	.25
Depreciation—irrigation and farm equipment	8.32	.90	7.40	.90	8.00	.90
Total	$224.44	$153.20	$360.15	$224.93	$152.97	$122.90

TABLE XXIII. ITEMIZED COST OF PRODUCING IRRIGATED AND NON-IRRIGATED BLACK RASPBERRIES ON EXPERIMENT STATION FARM
1928, 1929, 1930

Item	Cost per acre					
	1928		1929		1930	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Man and horse labor						
Resetting plants	.....	.....	.....	.....	$ 2.91	$ 2.91
Pruning and training—man labor	$ 43.27	$ 43.27	$ 43.07	$ 43.09	56.75	52.82
Pruning and training—horse labor	.48	.45	.....	.....	.....	.....
Cultivating—man labor	22.18	22.18	22.54	22.55	23.05	21.45
Cultivating—horse labor	6.26	6.27	5.80	5.77	4.57	4.00
Cultivating—tractor labor	.....	.....	.....	.....	1.02	1.05
Irrigating—man labor	15.00	.....	9.77	.....	14.55	.....
Irrigating—horse labor	1.84	.....	.81	.....	1.48	.....
Fertilizing—man labor	.....	.....	16.91	16.91	.....	.....
Fertilizing—horse labor	.....	.....	1.00	1.00	.....	.....
Fertilizing—truck labor	.....	.....	6.27	6.27	.....	.....
Cover-cropping—man labor	4.91	4.91	.....	.....	.....	.....
Cover-cropping—horse labor	.94	.95	.....	.....	.....	.....
Trellising—man labor	38.05	38.05	.....	.....	.....	.....
Picking—man labor	55.18	23.44	109.52	69.77	75.69	21.41
Materials						
Fertilizer	.....	.....	4.83	4.82	.....	.....
Cover-crop seed	1.75	1.75	.....	.....	.....	.....
Supplies and repairs	14.55	14.55	5.00	5.00	15.00	15.00
General						
Land rental	15.00	15.00	15.00	15.00	15.00	15.00
Power cost for pumping	5.00	.....	2.78	.....	2.20	.....
Miscellaneous	.....	.....	2.00	2.00	.....	.....
Interest and depreciation						
Interest—irrigation and farm equipment	7.30	.35	6.05	.30	6.20	.25
Depreciation—irrigation and farm equipment	8.32	.90	7.40	.90	8.00	.90
Total	$240.03	$172.07	$258.75	$193.38	$226.42	$134.79

The average precipitation during the growing seasons at Corvallis for the years 1926 to 1930 was 1.19 inches below the normal precipitation the past 42 years (Table XXIV).

TABLE XXIV. COMPARISON OF ACTUAL AND NORMAL PRECIPITATION FOR GROWING SEASONS
1926 to 1930
Based on U. S. Weather Bureau data recorded at Corvallis by the Soils department, Oregon State Agricultural College

Month	1926	1927	1928	1929	1930	Average for five years 1926 to 1930	Average normal for 42 years
	Precipitation	Precipitation	Precipitation	Precipitation	Precipitation		
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
April	.80	1.56	4.57	3.63	2.97	2.70	2.70
May	1.81	1.83	.48	.40	1.14	1.13	1.88
June	.09	2.45	.40	1.28	.94	1.03	1.15
July	.00	.02	.03	.00	.00	.01	.30
August	1.66	.21	.00	.03	.00	.38	.42
Total for growing season	4.36	6.07	5.48	5.34	5.05	5.25	6.45

Part II

SUGGESTIONS FOR THE BERRY IRRIGATOR

The experiments reported in the body of this Bulletin have not yet reached the point where it has been found possible to study in detail the many problems as to the proper time, amount, or manner of application of irrigation water. It is believed that the data reported show conclusively that the irrigation of these crops will increase the prospective profits under conditions similar to those of this experiment.

It is recognized that irrigation is not a standard practice in the Willamette Valley and that, therefore, berry growers who may contemplate the use of irrigation water will desire brief, practical suggestions on the methods to be followed. The following recommendations are based in part on the information obtained in the conduct of the experiment reported herein but more largely on general experience and observations of both experimental and practical farm work.

Water supply and equipment. In the Willamette Valley, irrigation water in some instances may be obtained from surface ponds or streams. If the water supply is from one of the streams issuing from the foot-hills it may be possible to construct a small dam across the stream and thus divert the water into a ditch. If this can be done a survey with a level will show whether it is possible to conduct the water in an open ditch to a point where it can be spread over the proposed berry yard.

If the supply is to be obtained from a pond or a slowly moving stream it will be necessary to use a pump to raise the water to the high point of the land to be irrigated. In most cases a centrifugal pump will be found most satisfactory for this purpose. The size of pump required will depend on many factors.

If electricity is used for pumping, the pump and motor should be as small as other conditions will permit in order that advantage may be taken of the lower energy rates obtained by pumping many hours during each month.

If a gas engine or tractor is used the most economical fuel consumption will be obtained with a pump which requires the engine to run at about its rated horse-power.

There is no advantage in installing equipment which is larger than that required to take care of the stream of water available.

If less than 20 acres are to be irrigated a stream of 225 to 350 gallons per minute is desirable to give a fair sized irrigating stream. If more than that area is to be covered the supply should be equal to 10 gallons per minute for each acre. This amount will supply a 4-inch irrigation in 15 days if irrigation is carried on for 12 hours every day. Lower energy costs will be obtained under the usual electric power schedules if smaller equipment is used and the hours of use per day increased.

If the berries are being grown on sandy or gravelly soil the size of the stream and the frequency of irrigation required will be increased. If the soil is somewhat tight, satisfactory results may be obtained in the irrigation of small yards with smaller streams than 225 gallons per minute.

In considering the amount of water required, the grower should not overlook the fact that while irrigation is being carried on, the water will need almost constant attention. If too small a stream is used the time spent in watching it will be excessive.

In many places in the Willamette Valley water can be obtained most readily from underground sources. Where a satisfactory supply of water can be obtained from coarse gravel within 20 or 30 feet of the surface a dug pit or well may be used. There is no advantage in digging a well pit larger than will accommodate the pump. If the water is found at a greater depth or the well must penetrate solid rock or quicksand a drilled well will often be found more economical.

If the level of the water in the well during pumping is not more than 15 feet below the ground surface a horizontal centrifugal pump may be installed on the surface of the ground. If the level of the water during pumping is more than 15 feet below the surface and a pit is used, a vertical centrifugal pump or, sometimes, a horizontal pump directly connected to an electric motor may be set down in the pit to within 15 feet of the lowest water-level.

If the water-level is low or subject to large fluctuations in a drilled well, a deep-well centrifugal pump of either the turbine or the direct-flow type should be used. The same considerations as to size apply to pumps used in pumping from wells as to those used in pumping surface water.

In addition, the fact that the water-level in a well will be lowered almost in proportion to the size of the stream of water pumped, makes it desirable not to pump a well more heavily than necessary.

Irrigation of berries. Before berries are planted the land should be leveled for irrigation. Much labor in the application of water and much water will be saved if this job is well done. It is necessary also to build up the fertility of the subsoil where it has been exposed by leveling.

Berries are almost always irrigated by allowing the water to flow down one or two furrows on each side of the berry rows. It is possible that some yards which are so rolling or so sandy that surface irrigation is very difficult may be irrigated by sprinkling. Sprinkler irrigation may also be used where only a small stream of water is available. No studies of this method of irrigation of berries have as yet been made in Oregon and, therefore, the practicability of this method under Willamette Valley conditions is unknown.

Amount of water. The amount of water which should be applied at each irrigation will depend on the crop grown, the type of soil, and the period between irrigations. Each type of soil has a very definite capacity for holding water. When the soil has been dried out by crops, it should be moistened to full capacity of the root zone but no more water than this should be applied. In general, it is believed that single applications of irrigation water should be equal to from 3 to 6 inches in depth over the surface. If the size of the stream being used is known, the depth applied may be easily found from the fact that a stream of 450 gallons per minute will cover an acre to a depth of one inch in one hour. To figure the area covered to a depth of one inch in one hour by any other stream, simply divide the size of stream used, in gallons per minute, by 450 and the result is the

area covered an inch deep every hour. Thus a stream of 200 gallons per minute will cover 200 divided by 450 or 44/100 of an acre an inch deep each hour.

The number of irrigations required will depend very largely on the season. It is believed that in most years three or four applications will be about right. If the season is unusually dry an extra application may be required in May.

Promptness in applying water when needed is of major importance, so that any set-back and delay in steady growth and development of fruit may be avoided.

The cost of irrigation increases with quantity used so that efficiency in use of water is essential to maximum profit. A good state of soil fertility is of fundamental importance in securing economic use of irrigation water.

Water is more effective if applied at the proper time. Since root activity precedes top growth it seems important to irrigate small fruit early on the Western Oregon river-bottom soils. It has been found desirable to apply the first irrigation to free working river-bottom soils the latter part of May. Water is more easily and uniformly applied before the soil is thoroughly dried out. The time and frequency of irrigation should be such as to provide a fairly uniform and medium soil moisture content.

Cost of power. The cost of power for pumping for irrigation is subject to great variation and much misapprehension. Where water is pumped to considerable elevations for field crops the cost of power is a very important factor. The data presented in the body of this Bulletin show that for the irrigation of berries the cost of power under ordinary conditions is a small fraction of the cost of production. With properly designed systems the cost of electric power should be about $3.00 or $4.00 per acre and should not exceed $6.00. This would probably represent a range of from 2 percent to 5 percent of the total cost of producing berries.

REFERENCES

More detailed information regarding irrigation methods may be obtained in the following bulletins.

Oregon Agricultural Experiment Station Bulletin 235, The Economic Limit of Pumping for Irrigation.

United States Department of Agriculture Farmers' Bulletin 864, Practical Information for Beginners in Irrigation.

United States Department of Agriculture Farmers' Bulletin 1404, Pumping from Wells for Irrigation.

United States Department of Agriculture Farmers' Bulletin 1635, Surface Irrigation in the Eastern States.