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The Irrigation of High Value Crops in New York

A Summary of Experimental Results and Discussion of the Economics of Irrigation

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The experimental results presented in this publication have been summarized from the reports of research conducted by members of the Departments of Vegetable Crops and Pomology, Cornell University, at the Ithaca, Geneva, Poughkeepsie and Riverhead Stations. Relevant parts of this report were reviewed by Professors C.G. Forshey, A.J. Pratt, and M.T. Vittum. Their help and cooperation made it possible to prepare such a summary.

This report is a contribution to the Northeast Regional Research Project on the Economics of Irrigation and was prepared under the direction of Professor B.F. Stanton, Department of Agricultural Economics, Cornell University.

INTRODUCTION

Irrigation is an important practice on many farms in New York. It has been used primarily in this state on high value crops - potatoes, vegetables, and fruit - by farmers who have access to surface water at relatively low cost. Most of those who have irrigation systems are convinced that they have been profitable investments. However, a few men who purchased large systems have since sold them for a variety of reasons.

Many things are not yet known about irrigation. Further research must be done to answer more fully such questions as:

(1) How much water should be applied at each watering for different crops on a given soil type?
(2) When should this water be applied?
(3) How can a farmer tell that it is time to irrigate?
(4) What is the best way of applying water to each crop?
(5) How can the efficiency of systems in delivering water to plants be increased?

These questions are most important to the farmer who has already invested in irrigation equipment and committed himself to the practice. However, they are also important to the man considering the installation of an irrigation system.

When buying an irrigation system, a farmer should know if the costs involved will be covered by the value of increased production and/or improved quality of the crops irrigated. The man who already has a system has to decide which of the crops he grows is the most profitable to irrigate.

Ideally each farmer should have some idea of what effect additional water "when needed" will have on yields and quality for each crop he might grow under his particular conditions over a period of years. Exact information of this kind is very difficult to obtain. Because conditions that affect crop yields - sunlight, rainfall, soils, fertility levels, and management ability - vary so much across New York State, information on yield responses to irrigation obtained on any one farm or from any one experiment may not apply generally. However, the results of farmers' experiences and controlled experiments can give some indication of costs and returns that may be expected for different crops. Each farmer must then interpret these results for his own farm.

This summary of experiments involving irrigation of vegetables and fruit within New York shows in brief what has been learned about the irrigation of some crops under specific sets of conditions. These summaries do not attempt to give complete reports of these experiments. In each case reference will be made to publications or other sources where more information on each experiment can be obtained. The summaries present the experimental results only - the profitability of irrigating these crops is discussed in a separate section.

Experiments involving irrigation have been undertaken for a small number of crops in New York State, covering a brief span of years and at a small number of locations. This is understandable when one considers the cost of such experiments. Despite this rather narrow range of experimental evidence there are some fairly clear indications from the experiments already conducted that irrigation is likely to be - or not to be - profitable for each crop considered.

This bulletin summarizes information from experiments on the effect of irrigation on the following high value crops:

I Apples
- a. Hudson Valley (1957) experiment continuing.

II Snap beans
- a. Ithaca (1955-57), experiment continuing.
- b. Geneva (1956-57), experiment continuing.

III Cabbage
- a. Geneva (1952-55)

IV Sweet corn
- a. Geneva (1952-56)
- b. Ithaca, Dundee, Penn Yan (1954-55)

V Peas
- a. Geneva (1952-57), experiment continuing.
- b. Ithaca, Dundee, Penn Yan (1954-55)

VI Potatoes
- a. Riverhead, Long Island (1938-45)
- b. 8 counties in up-state New York (1949-51)
- c. Riverhead, Long Island (1949-51)
- d. Ithaca (1952-53)

VII Tomatoes
- a. Geneva (1952-57), experiment continuing.
- b. Ithaca, Dundee, Penn Yan (1954-55)
- c. Ithaca (1955-57), experiment continuing.

Irrigation yield experiments on these crops were chosen for discussion because of the economic importance of each crop to the agriculture of New York State. 1/

1/ Irrigation experiments have also been conducted on the following less important crops. A brief citation to the source of further information is also given.

Lima beans (Ithaca, Pratt, 1954-55)
Onions (Ithaca, Pratt, 1952-53)
Radishes (Ithaca, Pratt, 1955-57)
Squash (Geneva, Vittum, 1957)

Irrigation experiments with alfalfa and pasture are likewise not considered. Agronomy Memo 945 (Jan. 1954, out of print) presents the results of a number of such experiments. The Geneva irrigation experiment has also included alfalfa in its rotation.

All the Geneva results are from a large scale irrigation experiment involving vegetables for processing. The first of two five-year rotations, with five crops, began in 1952. The objectives of this experiment, and the methods used, are discussed in "Soils and Methods Used in Irrigation Experiments at Geneva, N.Y.", by Vittum and Peck, Cornell University Bulletin 775, Geneva Experiment Station, March 1956. Additional results from the same experiment can be found in Peck and Vittum, "Evapo-Transpiration Rates for Alfalfa and Vegetable Crops in New York", Agronomy Journal, 50: 109-112, February 1958.

EXPERIMENTAL SUMMARIES

In most years in the Northeast total rainfall is sufficient for the crops grown, but the distribution of rainfall within the growing season is often most irregular, and not sufficient for crop needs. The yield response to irrigation will therefore vary from year to year. Experimental results covering a period of years will give the best indication of whether or not yield increases from irrigation are sufficient to cover the costs of applying the necessary water.

All of the recent experiments involving irrigation treatments for a selected group of crops have been listed above. The summaries cover the following aspects of each experiment: time; location; soils; experimental procedure, including the object of the experiment, experimental layout, irrigation and rainfall, fertilizer, other practices, spacing, varieties grown, length of growing season; and the experimental results as they relate to yield and quality changes from the irrigation water supplied. These summaries emphasize only the aspects of each experiment that particularly relate to irrigation. One must go to the original publications themselves for a full report of each experiment. The economic implications of these research results are discussed in a separate section (pp. 32-39).

Apples

1. SUMMARY OF HUDSON VALLEY FRUIT INVESTIGATIONS LABORATORY WORK.

Source of Data: Forshey, C.G., "Irrigating New York Orchards", Proceedings of the 103rd Annual Meeting, New York Horticultural Society, 1958, pp. 90-94.

Time: 1957 and continuing.

Location: Lagrangeville, Dutchess County, New York

Soils: Hoosic Gravelly Loam, a well-drained to droughty soil, strongly acid, low in lime, potash, phosphorus and nitrogen, but quite productive with fertilization and good management.

Experimental Procedure:

Treatments: Six irrigation treatments - from a high of 3" of water applied whenever field capacity dropped to 50% at the 12 inch level to no additional water. Each treatment consisted of one row of 21 trees.

Rainfall and Irrigation: A maximum of 12" of water was applied (i.e. in four applications). Irrigation started on the 18th of June, somewhat later than desired owing to heavy June drop in rows originally selected. New rows had to be substituted. Available soil moisture on the 18th of June was 20% for all experimental rows.

For treatments A-D soil moisture was above 25% for almost all summer (irrigation water applied varied from 7½ to 12 inches) while for treatments E (3 inches applied in mid-June) and F (control) soil moisture was below 25% for almost the whole summer.

Rainfall from May 1st to October 17th was 10.4 inches, but only 2.3 inches fell in August and September.

Fertilizer: ½ lb. actual N per tree.

Tree Spacing and Variety: There were 54 nine-year old Golden Delicious trees per acre.

Results: Irrigation improved both fruit size and yield. Additional yield due to irrigation equalled 158 boxes per acre, or an increase of 75% between the "no" and the "high" irrigation treatments. The number of 2-3/4" and up apples was increased by 197 boxes per acre. Irrigation increased the number of fruits per tree by reducing June drop.

Warning: Forshey, p. 93 - "This was a young orchard, only 9 years old, located on a soil that was likely to respond favorably to irrigation. But even more important, the month of June was unusually dry."

Snap Beans

1. SUMMARY OF ITHACA STATION WORK.

Source of Data: Effect of Irrigation and Mulch on the Yield and Quality of Snap Beans (and Tomatoes and Radishes) - a cooperative experiment conducted by the Departments of Vegetable Crops and Agricultural Engineering at Cornell University, 1955-57 inclusive (Mimeo reports by Pratt, A.J., Department of Vegetable Crops).

Time: 1955-57

Location: Ithaca, New York

Soil: Chenango Gravelly Silt Loam. This is a strongly acid and well-drained, but water-retentive soil. It is responsive to good management and fertilization with lime, phosphorus and (usually) potash.

Experimental Procedure: Four treatments without irrigation or mulching and with irrigation and mulching, separately and together replicated three times.

Rainfall and Irrigation: The plots were irrigated to field capacity when plants had used 50% of available water at the 6 and 12 inch levels.

	1955	1956 (inches)	1957
Growing season rainfall	10.1	8.2	8.9
Irrigation	9.2	2.0	0.3
Total	19.3	10.2	9.2
Number of irrigations	9	9	1

Fertilizer: 1500 pounds per acre of 5-10-10 ($38 worth per acre at 1956 prices).

Spacing: One inch between plants in 24 inch rows, i. e. much denser spacing than normal (3 x 36 inches).

Varieties: Regular Tendergreen (1955), Long Tendergreen (1956), Slendergreen (1957). There is little difference between these varieties.

Results:

Quality Change: Longer and straighter pods.

Yield per Acre:

	1955	1956	1957	Three year average
	(tons per acre)			
With irrigation	8	10	9	9.0
Without irrigation	3	8	8	6.3
Increase due to irrigation	5	2	1	2.7
Percentage increase	167%	25%	12%	42%

COMPARIBILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Snap beans for fresh market, New York	1949-54 average	1955	1956	1957
Acres harvested	12,200	11,700	11,600	10,700
Yield, tons per acre	2.1	2.0	1.9	2.2
Price per ton	$147	$147	$156	$164

Source: Vegetables for Fresh Market, Annual Summaries, A.M.S., U.S.D.A.

2. SUMMARY OF GENEVA STATION WORK

Snap beans were introduced into the large-scale irrigation experiment (see cabbage, peas, tomatoes, and sweet corn) at Geneva in the place of cabbage in 1956.

They have been grown for two years, 1956 and 1957. In 1956 no irrigation water was added, thus no response. In 1957, there was one irrigation of 1.4 inches, but it was not needed, and no yield response was recorded.

Cabbage

1. SUMMARY OF GENEVA STATION WORK

Source of Data: Vittum, M.T. and Peck, N.H., Response of Cabbage to Irrigation, Fertility Level, and Spacing, New York State Agricultural Experiment Station, Cornell University, Geneva, New York, Bulletin No. 777, November 1956.

Other Publications: Vittum, M.T., and Peck, N.H., "Proper Spacing and Irrigation Can Improve Your Cabbage", Farm Research, April 1954.

Time: 1952-55

Location: Darrow Farm, near Geneva, New York.

Soils: A 12 acre tile-drained field was used - 43% Lima, 47% Kendaia, and 10% Lakemont Silt Loam. The average pH prior to the experiment was 6.5. Normally these heavy high-lime soils are from "moderately well" to "poorly" drained. They are typical of soils used for vegetable growing in many parts of Western New York.

Experimental Procedure:

Crops: Five year rotation of tomatoes, cabbage, sweet corn, peas (alfalfa), and alfalfa.

Rainfall and Irrigation: "Each field was divided into six main plots, three of which were not irrigated. The remaining three plots were irrigated whenever 'available' soil water in the upper 24 inches dropped below 50%". (Bull. 777, p. 4.)

	1952	1953	1954	1955
		(inches)		
Rainfall, June - Sept.	10.6	11.4	9.9	11.9
Irrigation	4.9	3.7	4.0	4.7
Total	15.5	15.1	13.9	16.6
Number of irrigations	3	2	3	3

Fertilizer: One-half of all plots received "normal" recommended application for the particular crop being grown, i.e. an average of 800 lbs. of 8-16-16 per year, and the other half received twice this amount of fertilizer. Each plot received the same fertilizer treatment throughout the course of the experiment. Cumulative effects of different fertilizer treatments could be examined as a result.

Spacing: For cabbage each of the irrigation - fertility level subplots was further sub-divided into 4 spacing treatments, plant spacing of 12, 18, 24, and 36 inches in 3 foot rows. There were 12 replications of spacing treatments, 6 replications of fertility level, and 3 replications of irrigation in a split, split plot design.

Variety: Wisconsin All Season (11 of 12 replications). This is a sauerkraut variety.

Results:

Marketable Yield:

	Year	Irrigated	Non-irrigated	Increase
		(tons per acre)		
Normal Fertility, 24 inch spacing	1952	32.7	28.8	3.9
	1953	28.4	24.1	4.3
	1954	20.4	17.6	2.8
	1955	23.3	22.2	1.1
	Average	26.2	23.2	3.0 or 13%
	1952	35.6	32.8	2.8
Normal Fertility, 12 inch spacing	1953	31.6	25.0	6.6
	1954	25.8	22.6	3.2
	1955	33.7	27.3	6.4
	Average	31.7	26.9	4.7 or 17%

Differences in fertility level had very little effect on yields per acre of marketable heads. "Obviously this 0.6 ton increase will not pay for the approximately 800 lbs. per acre per year of 8-16-16 fertilizer (cost $30 at 1956 prices) which were applied" in addition to normal fertilizer applications (Bulletin 777, p. 21).

The dominant effect on yields of both spacing and irrigation is shown in the above tables.

The effect of irrigation on number of plants per acre was slight, but favorable. Its effect on number of burst heads was likewise slight, though generally unfavorable. Marketable yield data take these factors into account.

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Commercial crop for sauerkraut, New York	1945-54 average	1952	1953	1954	1955
Acres	6550	7000	5500	4900	5000
Yield, tons per acre	13.0	12.9	16.5	15.9	13.0
Price per ton	$13.50	$23.20	$12.40	$10.50	$22.20

Source: Vegetables for Processing, Annual Summaries, A.M.S., U.S.D.A.

Sweet Corn

1. SUMMARY OF GENEVA STATION WORK

Source of Data: Vittum, M.T., Response of Sweet Corn to Irrigation with Differential Spacing and Fertility, New York State Agricultural Experiment Station, Cornell University, Geneva, New York - Bulletin to be published in 1958.

Time: 1952-56

Location: Darrow Farm, near Geneva, New York

Soils: A 12 acre tile-drained field was used - 43% Lima, 47% Kendaia, and 10% Lakemont Silt Loam. The average pH prior to the experiment was 6.5. Normally these heavy high-lime soils are from "moderately well" to "poorly" drained. They are typical of soils used for vegetable growing in many parts of Western New York.

Experimental Procedure:

Crops: Five year rotation of tomatoes, cabbage, sweet corn, peas (alfalfa), and alfalfa.

Rainfall and Irrigation: Each field was divided into six main plots, three of which were not irrigated. The remaining three plots were irrigated whenever "available" soil water in the upper 24 inches dropped below 50%. Water was added until "available" moisture reached 90% of field capacity.

	1952	1953	1954	1955	1956
			(inches)		
Rainfall, June - Sept.	10.6	11.4	9.9	11.9	10.8
Irrigation water	2.9	1.8	5.5	6.5	none
Total	13.5	13.2	15.4	18.4	10.8
Number of applications	2	2	4	4	none

Fertilizer: Applications at normal fertility level, five year average rates. The high fertility plots received twice as much P_2O_5 and K_2O, and slightly more than twice as much N per acre per year as the normal fertility plots. Average annual fertilizer costs per acre for normal, and high fertility plots were about $13 and $29 respectively (at 1956 prices).

Spacing: Five different spacings were used for plants in the row. Row width was 3 feet. These spacings were designed to provide five levels of plant density per acre, 10,000; 12,000; 14,000; 16,000; and 18,000 plants per acre. Average within row spacings were $17\frac{1}{2}$, $14\frac{1}{2}$, $12\frac{1}{2}$, 11 and 10 inches.

Varieties: Golden Crown, 1952-54; Victory Golden, 1955-56.

Results: Results for the 18,000 and 14,000 plants per acre treatments are shown below. The higher plant densities consistently showed higher yields per acre.

Yield Response to Irrigation: Yield response to irrigation has varied from year to year, but yield increases have occurred in each year that irrigation water was applied. Yield variability has also been reduced. (The average increase in yield per acre, for all varieties, was calculated to be 0.33 tons per inch of water applied.)

Yield Response to Additional Fertilizer: Yield response to additional fertilizer above normal fertility level has been small or negative on both non-irrigated and irrigated plots. The value of yield response to additional fertilizer was not sufficient to cover costs.

Yield of Unhusked Corn Per Acre:

	Year	Irrigated	Non-irrigated	Increase
		(tons per acre)		
Normal Fertility, 18,000 plants per acre	1952	7.0	6.0	1.0
	1953	6.0	4.6	1.4
	1954	5.6	2.8	2.8
	1955	6.4	5.3	1.1
	1956	6.6	7.0	-0.4
	Average	6.3	5.1	1.2 or 23%
Normal Fertility, 14,000 plants per acre	1952	6.8	6.1	0.7
	1953	5.5	4.6	0.9
	1954	5.5	2.8	2.7
	1955	6.0	5.0	1.0
	1956	6.4	7.1	-0.7
	Average	6.0	5.1	0.9 or 18%

Length of Growing Season: For non-irrigated plots the average length of the growing season was 92.9 days (range 89.7 to 99.3 days), and for the irrigated plots it was 95.1 days (range 89 to 99.7 days).

Number of Ears per Plant: Irrigation increased the average number of ears per plant from 1.09 to 1.19 (1952-56 average).

Average Weight per Ear: Irrigation increased the average weight per ear from 0.67 lbs. to 0.76 lbs. (1952-56 average).

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Commercial crop for processing, sweet corn, New York	1945-54 average	1952	1953	1954	1955	1956
Acres	24,900	25,500	24,900	21,000	15,300	18,800
Yield, tons per acre	2.7	2.8	3.2	3.0	2.8	3.1
Price per ton (unhusked corn)	$21.90	$26.30	$24.60	$22.10	$19.70	$22.00

Source: Vegetables for Processing, Annual Summaries, A.M.S., U.S.D.A.

Note: Experimental yields have been almost double average farm yields.

2. SUMMARY OF ITHACA STATION WORK

Source of Data: Pratt, A.J., and Ruf, R.H., Irrigation and Mulch for Vegetables, Mimeo Reports of 1954 and 1955 Test Plots in New York State, November 1955.

Time: 1954-55

Location: Ithaca, Dundee, and Penn Yan, New York.

Soils: At Ithaca - Chenango Gravelly Silt Loam. This is a strongly acid and well-drained, but water-retentive soil. It is responsive to good management, and fertilization with lime, phosphorus and (usually) potash.

At Dundee - Volusia Stony Silt Loam. This is a somewhat poorly drained, and strongly acid soil. It is of low natural fertility, and needs heavy liming and fertilization; it can be adapted for corn, small grains, and hay exclusive of alfalfa.

At Penn Yan - Ontario Fine Sandy Loam. This is a high-lime well-drained soil. It is usually associated with rolling topography, and subject to erosion. Phosphorus is consistently deficient.

Experimental Procedure:

Crops: Four crops were included in these small plot experiments - tomatoes, sweet corn, peas, and lima beans. Four treatments were considered: without irrigation or mulching, with irrigation alone, with mulching alone, and with both together.

Rainfall and Irrigation: One inch of irrigation water was applied whenever soil water dropped to 50% of soil capacity.

	1954	1955
	(inches)	
Ithaca		
Rainfall, June - Sept.	9.4	11.0
Irrigation	6.0	8.6
Total	15.4	19.6
Number of irrigations	6	8
Dundee		
Rainfall, June - Sept.	8.0	9.6
Irrigation	2.2	7.0
Total	10.2	16.6
Number of irrigations	2	7
Penn Yan		
Rainfall, June - Aug.	8.5	8.0
Irrigation	3.2	7.0
Total	11.7	15.0
Number of irrigations	3	7

Mulching: $1\frac{1}{2}$" of sawdust.

Fertilizer: 1500, 1200 and 1800 lbs. per acre of 10-20-20 at each location ($66, $52, and $79 respectively).

Spacing: 9" in rows, 30" between rows.

Variety: Seneca Chief.

Results:

Quality: No detectable change in flavor, definite increase in size of ear.

Yield of Unhusked Corn per Acre:

	1954	1955
	(tons per acre)	
Ithaca		
With irrigation	7.2	5.1
Without irrigation	4.3	3.2
Increase due to irrigation	2.9	1.9
Percentage increase	70%	59%
Dundee		
With irrigation	2.4	2.3
Without irrigation	2.1	1.6
Increase due to irrigation	0.3	0.7
Percentage increase	14%	44%
Penn Yan		
With irrigation	*	5.6
Without irrigation	*	2.8
Increase due to irrigation	*	2.8
Percentage increase	*	100%

* Not available.

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Commercial crop for fresh market, New York	1949-54 average	1954	1955
Acres	21,900	20,000	19,000
Yield, tons per acre	3.0	2.9	2.9
Price per ton	$50.40	$59.40	$50.00

Source: Vegetables for Fresh Market, Annual Summaries, A.M.S., U.S.D.A.

Note: The average yields per acre on the no irrigation experimental plots are close to the state average yields in 1954 and 1955.

Peas

1. SUMMARY OF GENEVA STATION WORK

Source of Data: Vittum, M.T., Peck, N.H., and Sayre, C.B., Response of Processing Pea Varieties to Irrigation and Other Factors Affecting Yield. Unpublished results from work done at New York State Agricultural Experiment Station, Cornell University, Geneva, New York.

Other Publications: Vittum, M.T., Peck, N.H., and Sayre, C.B., "Response of Peas to Variable Row Spacings and Plant Populations", Agronomy Journal.

Time: 1952-57

Location: Darrow farm, near Geneva, New York.

Soils: A 12 acre tile-drained field was used - 43% Lima, 47% Kendaia, and 10% Lakemont Silt Loam. The average pH prior to the experiment was 6.5. Normally these heavy high lime soils are from "moderately well" to "poorly" drained. They are typical of soils used for vegetable growing in many parts of Western New York.

Experimental Procedure:

Crops: Five year rotation of tomatoes, cabbage, sweet corn, peas (alfalfa), and alfalfa. Peas were not planted in 1956 owing to the wet conditions at planting time.

Rainfall and Irrigation: Each field was divided into six main plots, three of which were not irrigated. The remaining three plots were irrigated whenever "available" soil water in the upper 24 inches dropped below 50%. Water was added until "available" moisture reached 90% of field capacity.

	1952	1953	1954	1955	1957
	(inches per acre)				
Rainfall, planting to harvest	7.0	7.6	5.2	3.7	6.9
Irrigation water	2.5	1.8	2.4	5.1	1.8
Total	9.5	9.4	7.6	8.8	8.7
Number of applications	2	2	4	6	2

Fertilizer: An average of 470 pounds of 10-10-10 fertilizer was applied per acre per year. This was considered to be the normal fertility level. A high fertility level of about 900 pounds of 10-10-10 per acre was also included in the treatments. Fertilizer cost per acre per year was $16 and $30 at the normal and high fertility levels respectively (at 1956 prices).

Seeding Rate: For the first three years there were differential row spacings. In 1955 and 1957 all rows were 7 inches apart. In both experiments four seeding rates were used, from normal (3.6 bush. per acre - $29) to half-normal (1.8 bush. per acre - $15). All results quoted are for normal seeding rates, which produced the highest yields.

Variety: Perfection, a processing variety.

Results:

Quality Changes: The quality of processing peas is often measured by a tenderometer. The higher the tenderometer reading may be, the lower the price paid per ton. Processing varieties used for freezing should give a tenderometer reading of 90, for canning a reading of 100 is satisfactory.

Generally speaking the higher the yield, the higher the tenderometer reading - in other words as output per acre increases, price per ton decreases.

TENDEROMETER READINGS AT NORMAL SPACING AND FERTILITY

Year	Irrigated	Non-irrigated	Difference: Irrigated minus Non-irrigated
1952	101	108	-7
1953	128	117	9
1954	90	100	-10
1955	149	109	40
1957	101	113	-12

Yield per Acre, Normal Fertility:

Year	Irrigated	Non-irrigated	Increase
		(pounds per acre)	
1952	4910	4810	100
1953	5770	4570	1200
1954	2130	2570	- 440
1955	7160	3250	3910
1957	3510	4620	-1110
Average	4700	3960	740 or 19%

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Peas, commercial crop for processing, New York	1945-54 average	1952	1953	1954	1955	1957
Acres	27,900	22,500	22,700	17,600	21,100	15,500
Yield, pounds per acre	1,720	1,530	1,780	1,700	1,850	2,580
Price per ton	$ 93	$101	$115	$106	$101	$ 99

Source: Vegetables for Processing, Annual Summaries, A.M.S., U.S.D.A.

2. SUMMARY OF ITHACA STATION WORK

Source of Data: Pratt, A.J., and Ruf, R.H., Irrigation and Mulch for Vegetables, Mimeo Report of 1954 and 1955 Test Plots in New York State, November 1955.

Time: 1954-55

Location: Ithaca, Dundee, and Penn Yan, New York.

Soils: At Ithaca - Chenango Gravelly Silt Loam. This is a strongly acid and well-drained, but water retentive soil. It is responsive to good management, and fertilization with lime, phosphorus and (usually) potash.

At Dundee - Volusia Stony Silt Loam. This is a somewhat poorly-drained, and strongly acid soil. It is of low natural fertility, and needs heavy liming and fertilization; it can be adapted for corn, small grains, and hay exclusive of alfalfa.

At Penn Yan - Ontario Fine Sandy Loam. This is a high lime, well-drained soil. It is usually associated with rolling topography, and subject to erosion. Phosphorus is consistently deficient.

Experimental Procedure:

Crops: Four crops were included in the small-plot experiment - tomatoes, sweet corn, peas, and lima beans. Four treatments were considered: without irrigation or mulching, with irrigation alone, with mulching alone, and with both together.

Rainfall and Irrigation: One inch of irrigation water was applied whenever soil water dropped to 50% of soil capacity.

Ithaca	1954	1955
	(inches)	
Rainfall, growing season	5.9	5.2
Irrigation	2.0	6.2
Total	7.9	11.4
Number of irrigations	2	6

Dundee	1954	1955
Rainfall, growing season	5.3	0.4
Irrigation	2.2	6.0
Total	7.5	6.4
Number of irrigations	2	6

Penn Yan	1954	1955
Rainfall, growing season	5.8	2.0
Irrigation	3.2	6.0
Total	9.0	8.0
Number of irrigations	3	6

Mulching: $1\frac{1}{2}$ inches of sawdust.

Fertilizer: 1500, 1200 and 1800 pounds per acre of 10-20-20 at each location ($66, $53 and $79 respectively).

Spacing: Not stated.

Variety: Not stated.

Results:

Yield per Acre:

Ithaca	1954	1955
	(pounds per acre)	
With irrigation	5400	3900
Without irrigation	4300	2900
Increase due to irrigation	1100	1000
Percentage increase	26%	34%

	1954	1955
	(pounds per acre)	
Dundee		
With irrigation	3900	1300
Without irrigation	1700	800
Increase due to irrigation	2200	500
Percentage increase	130%	62%
Penn Yan		
With irrigation	3300	1400
Without irrigation	3100	1000
Increase due to irrigation	200	400
Percentage increase	6%	40%

Potatoes

1. SUMMARY OF LONG ISLAND RESEARCH STATION WORK (1938-45)

Source of Data: Hampton, R.N., Murphy, R.G., and Holt, P.R., Potato Irrigation: Costs and Practices in Suffolk County, New York, 1946, Cornell University Agricultural Experiment Station Bulletin 862, September 1950.

Time: 1938-45

Location: Long Island Vegetable Research Farm, Riverhead, New York.

Soil: Sassafras Silt Loam, a light, well to excessively-drained acid soil.

Experimental Procedure:

Rainfall and Irrigation: 1938-40 inclusive - water was applied (including rainfall) at a rate of one inch per week, cumulative.

1941-45 inclusive - same as for previous period, except that all irrigation was undertaken between June 1st and August 15th. Amount of water added averaged three irrigations of 1.4 inches each.

The proper timing of irrigation was regarded as an unsolved problem.

Fertilizer: 2000 pounds of 5-8-5 per year, i.e., 100 pounds of N, 160 pounds of P_2O_5, and 100 pounds of K_2O per year.

Spacing: Not stated.

Variety: Green Mountain.

Cultural Practices: "were very similar to those used by farmers in the area" (Bull. 862, p.25).

Results:

Quality Change: No information on quality change is given, though it is stated that irrigation does tend to improve overall quality.

A series of fertilizer experiments undertaken in conjunction with the irrigation experiments showed higher yield increases with added fertilizer.

Yield: (Bulletin 862, p.25)

SUMMER RAINFALL AND YIELD OF POTATOES, IRRIGATED AND NON-IRRIGATED PLOTS, LONG ISLAND VEGETABLE RESEARCH FARM

Year	Yield per acre Non-Irrigated (bushels)	Yield per acre Irrigated (bushels)	Increase per acre (bushels)	Per cent increase	Rainfall June-August (inches)
1938	429	430	1	*	15.0
1939	150	361	211	141	10.8
1940	218	252	34	16	10.6
1941	350	407	57	16	11.5
1942	252	231	- 21	negative	15.6
1943	215	204	- 11	negative	10.4
1944	113	268	155	137	3.5
1945	342	275	33	10	7.4
Average	259	316	57	22	10.6

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE - FOR LONG ISLAND POTATOES

	1936-45 average
Acres harvested	56,000
Yield per acre, bushels	226
Price per bushel	$1.07

Source: Agricultural Statistics, U.S.D.A.

2. SUMMARY OF ITHACA STATION WORK (1949-51)

Source of Data: Pratt, A.J.; Lamb, Jr., J.; Wright, J.D.; and Bradley, G.A.; "Yield, Tuber Set, and Quality of Potatoes - Effect of Irrigation, Date of Planting, and Straw Mulch on Several Varieties in Upstate New York, 1948-1951", Cornell University Agricultural Experiment Station Bulletin 876, April 1952.

Time: 1949-51

Location: Experimental plots were located in Allegany, Cattaraugus, Chenango, Genesee, Onondaga, Tioga, Tompkins and Washington Counties, New York. This summary covers the experimental results from Genesee, Onondaga, and Tompkins Counties only.

Soils: Not stated.

Experimental Procedure: All plots were replicated (total size 128 x 135 feet). The 1949 plot plan gave two replications of irrigation, four replications of planting dates, eight replications of straw mulch, and sixteen replications of varieties. Subsequent plot plans involved more irrigation replicates. The straw mulch and the different planting dates treatments were omitted.

Rainfall and Irrigation: In 1949, 1950, and 1951 all irrigating was done by the authors. A practicable portable irrigation system was not ready until July 1949, making it too late for proper irrigation in all counties except Chenango that year.

Water was applied whenever soil moisture dropped below 50% of field capacity. The "effect" of the irrigation (in terms of amount supplied in relation to field capacity) is not recorded.

	1949	1950 (inches)	1951
Genesee			
Rainfall, June - August	14.1	8.6	7.5
Irrigation	7.0	1.0	2.9
Total	21.1	9.6	10.4
Number of irrigations	6	1	3
Onondaga			
Rainfall, June - August	---	10.0	10.3
Irrigation	---	3.0	2.0
Total	---	13.0	12.3
Number of irrigations	---	3	2

	1949	1950 (inches)	1951
Tompkins			
Rainfall, June - August	---	---	12.1
Irrigation	---	---	2.0
Total			14.1
Number of irrigations	---	---	2

Fertilizer: 8-16-16 fertilizer was applied on all upland plots at the rate of 2000 pounds per acre (value of fertilizer equal to $74 per acre using 1956 prices).

Spacing: Within row spacing was 12 inches in 1949, and 9 inches in 1950 and 1951. The number of plants was increased in 1950-51 to decrease the number of over-size tubers per row.

Varieties: Chenango, Katahdin, and Kennebec.

Cultural Practices: "Standard".

Results:

Yield per Acre:

	1949	1950 (bushels per acre)	1951
Genesee			
With irrigation	689	273	287
Without irrigation	585	211	279
Increase due to irrigation	104	62	8
Percentage increase	18%	29%	3%
Onondaga			
With irrigation	---	486	504
Without irrigation	---	372	496
Increase due to irrigation	---	114	8
Percentage increase	---	31%	2%
Tompkins			
With irrigation	---	---	471
Without irrigation	---	---	404
Increase due to irrigation	---	---	67
Percentage increase	---	---	17%

Other: Irrigation depressed the yield of varieties which are susceptible to late blight.

3. SUMMARY OF ITHACA STATION WORK (1952-53)

Source of Data: Bradley, G.A., and Pratt, A.J., "Irrigate to Make a Crop, Not to Save It", Farm Research, pp. 10-11, Vol. XX, No. 2, April 1954.

Time: 1952-53

Location: Ithaca (1952-53) and Mount Pleasant (1952), New York.

Soils: At Ithaca - Dunkirk fine sandy loam.

At Mount Pleasant - Valois stony loam.

Experimental Procedure: The experiment was designed to determine the optimum time for irrigating.

Rainfall and Irrigation: In both 1952 and 1953 irrigation water was applied whenever soil water dropped to 50%, 25% or 5% of capacity. In 1952 irrigation was at the rate of one inch per watering; in 1953 each row was irrigated to capacity at each watering.

	1952 (inches)	1953
Ithaca		
Rainfall, growing season	10.6	10.2
Irrigation	11.0	6.8
Total	21.6	17.0
Number of applications	11	not stated
Mount Pleasant		
Rainfall, growing season	10.8	---
Irrigation	9.0	---
Total	19.8	
Number of applications	9	---

Fertilizer: Not stated.

Spacing: Not stated.

Variety: Kennebec

Results:

Yield per Acre:

	1952	1953
	(bushels per acre)	
Ithaca		
With irrigation	580	870
Without irrigation	400	550
Increase due to irrigation	180	320
Percentage increase	45%	58%
Mount Pleasant		
With irrigation	690	---
Without irrigation	620	---
Increase due to irrigation	70	---
Percentage increase	11%	---

Note: All results quoted are for highest irrigation level (see Rainfall and Irrigation table above).

The average yield increase reported for the three trials between irrigation at the 50% level and no irrigation was 200 bushels above the no irrigation per acre yield of 510 bushels. This is an increase of 39%.

The effect of irrigation on yield came from both improved tuber set and increased tuber size. The former was important in 1952.

Irrigation at lower levels of field moisture capacity produced markedly lower yield responses to irrigation.

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Potatoes, Upstate New York	1940-49 average	1949	1950	1951
Acres	114,000	76,000	64,000	54,000
Yield, bushels per acre	149	240	275	250
Price per bushel	$1.30	$1.13	$0.70	$1.45

Source: Agricultural Statistics, U.S.D.A.

4. SUMMARY OF LONG ISLAND RESEARCH STATION WORK (1949-51)

Source of Data: Jacob, W.C.; Russell, M.B.; Klute, A.; Levine, G.; and Grossman, R., "The Influence of Irrigation on the Yield and Quality of Potatoes on Long Island", *American Potato Journal*, Vol. 29, pp. 292-296, 1952.

Time: 1949-51

Location: Long Island Vegetable Research Farm, Riverhead, New York.

Soils: Sassafras silt loam, a light, well to excessively drained acid soil.

Experimental Procedure: The experiment was designed to make a more accurate determination of the optimum frequency and amount of irrigation water required over a number of seasons. There were 9 replications of each treatment.

Rainfall and Irrigation: All watering was done on the basis of soil moisture as determined by a tensiometer. Treatments were designated by the maximum tension permitted before water was applied. Sufficient water was applied in each case to bring the top 12 inches of soil in the plot up to field capacity.

Spray irrigation was used in 1949, but furrow irrigation was used in 1950 and 1951.

Maximum tension of mercury	Total water available per acre			Total irrigation per acre			Number of irrigations		
	1949	1950	1951	1949	1950	1951	1949	1950	1951
(inches)	(inches)			(inches)					
$2\frac{1}{2}$	----	25.9	----	----	11.3	----	----	26	----
5	20.9	24.1	24.3	10.9	9.5	11.3	10	14	17
10	18.7	23.3	23.1	8.7	8.7	10.1	7	11	9
20	15.9	21.8	20.0	5.9	7.2	7.0	4	6	4
40	----	21.4	18.6	----	6.8	5.6	----	3	3
no irrigation	10.0	14.6	13.0	0	0	0	0	0	0

Varieties: Katahdin (1949) and Green Mountain (1950 and 1951).

Fertilizer: In 1949, 2500 pounds of 5-10-5 was applied per acre and in 1951, 2000 pounds of 7-7-7 was applied per acre. (Fertilizer for 1950 was not stated.)

Spacing: Not stated.

Cultural Practices: "Standard"

Results:

Yield, as Influenced by Soil Moisture Content:

Maximum tension, inches of mercury	1949	1950	1951
		(bushels per acre)	
$2\frac{1}{2}$	---	528	---
5	443	546	477
10	459	552	465
20	419	554	499
40	---	574	442
No irrigation	258	537	367
Maximum response to irrigation:			
Additional yield per acre	201	37	132
Irrigation applied, inches	8.5	6.8	7.0
Minimum resonse to irrigation:			
Additional yield per acre	161	-9	75
Irrigation applied, inches	5.9	11.3	5.6

The average maximum yield increase from irrigation for 1949-51 was 32%; the average minimum response was 20%.

In 1949, a dry year, the only significant difference was between no irrigation and some irrigation.

In 1950, the major difference was between no irrigation and the 40 inches of tension. Higher soil moisture consistently reduced the yield. In 1951, maximum yields were attained when irrigation water was applied when tension was 20 inches.

Author's Conclusions: The exact optimum level of minimum soil moisture may vary from year to year, but it seems to be in the neighborhood of 20 to 40 inches of mercury tension or about 50 to 60% of field capacity.

Applications of one to two inches of water, applied frequently enough to prevent excessive drying of the soil, seemed to be adequate for potatoes on Long Island. Smaller and more frequent applications were not so good.

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Potatoes, Long Island, New York	1941-50 average	1949	1950	1951
Acres	61,000	54,000	46,000	48,000
Yield, bushels per acre	270	230	365	300
Price per bushel	$1.18	$1.13	$0.70	$1.45

Source: Agricultural Statistics, U.S.D.A.

Tomatoes

1. SUMMARY OF GENEVA STATION WORK (1952-57)

Source of Data: Vittum, M.T., and Sayre, C.B., Response of Tomato Varieties to Irrigation and Fertility Level, New York Agricultural Experiment Station, Cornell University, Geneva, New York, Bulletin to be published in 1958, covering results for 1952-56.

Other Publications: Tapley, W.T., Vittum, M.T., and Peck, N.H., "Choose the Right Tomato Variety If You Are Planning to Irrigate", Farm Research, June 1958.

Time: 1952-57.

Location: Darrow Farm, near Geneva, New York.

Soils: A 12 acre tile-drained field was used - 43% Lima, 47% Kendaia, and 10% Lakemont silt loam. The average pH prior to the experiment was 6.5. Normally these heavy high lime soils are from "moderately well" to "poorly" drained. They are typical of the soils used for vegetable growing in many parts of Western New York.

Experimental Procedure:

Crops: Five year rotation of tomatoes, cabbage, sweet corn, peas (alfalfa) and alfalfa.

Rainfall and Irrigation: Each field was divided into six main plots, three of which were not irrigated. The remaining three plots were irrigated whenever "available" soil water in the upper 24 inches dropped below 50%. Water was added until "available" moisture reached 90% of field capacity.

	1952	1953	1954	1955	1956	1957
	(inches per acre)					
Rainfall, June - Sept.	10.6	11.4	9.9	11.9	10.8	8.6
Irrigation	4.9	4.2	7.8	9.9	1.4	4.6
Total	15.5	15.6	17.7	21.8	12.2	13.2
Number of applications	3	3	5	6	2	3

Fertilizer: Applications at normal fertility level, five year average rates per acre.

The high fertility plots received twice as much fertilizer per year. Average fertilizer costs per acre for normal and high fertility levels were about $28 and $56 respectively (at 1956 prices).

Spacing: Three feet by five feet.

Varieties: A total of 12 varieties were tested. Each treatment was replicated three times. Six varieties were tested for the whole of the five-year period - Red Top, Longred, John Baer, Stokesdale, Red Jacket, and Gem. In 1957 many of these varieties were changed, but the two chosen for consideration, Red Jacket and Geneva 11 (see below) were continued in the experiment.

Results:

Quality: All yields are measured in terms of the quality that meets processors' requirements. Average yields per acre on a year to year basis compare quite closely with those for New York State as a whole.

Marketable Yield: In presenting yield information two varieties only have been selected. The first of these is Red Jacket, the variety most commonly grown for processing in the state. (Six years of records available.) The second is Geneva 11, a new variety of considerable promise. (Four years of records available.)

Red Jacket:

	Year	Irrigated	Non-irrigated	Increase
		(tons per acre)		
Normal fertility	1952	15.1	14.9	0.2
	1953	11.7	14.3	-2.6
	1954	16.0	8.9	7.1
	1955	16.6	6.9	9.7
	1956	2.5	3.9	-1.4
	1957	18.5	10.8	7.7
	Average1/	13.1	9.0	4.1 or 46%

Red Jacket: (con't)

	Year	Irrigated	Non-irrigated	Increase
		(tons per acre)		
High fertility	1952	14.0	17.7	-3.7
	1953	13.3	15.0	-1.7
	1954	16.6	8.6	8.0
	1955	16.2	8.0	8.2
	1956	2.9	4.6	-1.7
	1957	19.4	12.8	6.6
	Average 1/	13.7	9.8	3.9 or 40%

1/ Average for 1953-57.

The negative responses to irrigation in 1952 and 1953 should be noted; in 1952 a heavy crop of rye grass (not used subsequently) on the irrigated plots hid the fruit from the pickers, while in 1953 hot weather in September prevented the proper coloring of the fruit on the irrigated plots. The 1952 results are not included in the subsequent discussion.

Geneva 11:

	Year	Irrigated	Non-irrigated	Increase
		(tons per acre)		
Normal fertility	1954	16.8	11.8	5.0
	1955	16.8	7.9	8.9
	1956	5.0	6.5	-1.5
	1957	19.8	12.2	7.6
	Average	14.6	9.6	5.0 or 52%
High fertility	1954	17.6	10.0	7.6
	1955	18.8	8.5	10.3
	1956	6.5	8.4	-1.9
	1957	23.9	14.8	9.1
	Average	16.7	10.4	6.3 or 61%

Other: It should be noted that the two years which show high yield response, 1954 and 1955, were classified as dry years. 1956 was a wet year, and yield per acre was low because of early frosts. Both Red Jacket and Geneva 11 are late maturing varieties.

The interaction between variety and response to irrigation was highly significant. The two varieties considered here showed the largest responses to irrigation.

Irrigation leads to later average maturity in most cases, but brings about no overall deterioration in quality. Average mid-season quality is improved, but a lower proportion of the late crop can be classified as top quality. If drought occurs early in the season, however, timely irrigation may speed maturity.

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Commercial crop of tomatoes for processing, New York	1945-54 average	1952	1953	1954	1955	1956	1957
Acres	20,800	18,600	16,600	11,600	13,000	13,600	12,300
Yield, tons per acre	8.4	12.6	10.6	8.3	8.3	6.5	8.6
Price per ton	$29.30	$32.20	$30.90	$29.20	$31.50	$32.90	$35.70

Source: Vegetables for Processing, Annual Summaries, A.M.S., U.S.D.A.

Notes:

1. The experimental results seem quite comparable with farmer experience.

2. Tomato prices are to some extent influenced by local supply, but the acreage and yields in California have a much greater influence on realized prices in New York State.

3. No additional disease or insect problems were noted on the irrigated plots. Extra weeding was, however, necessary, raising per acre growing costs.

2. SUMMARY OF ITHACA STATION WORK (1954-55)

Source of Data: Pratt, A.J., and Ruf, R.H., Irrigation and Mulch for Vegetables, Information from Mimeo Reports of 1954 and 1955 Test Plots in New York State, November 1955.

Time: 1954-55

Location: Ithaca, Dundee, and Penn Yan, New York.

Soils: At Ithaca - Chenango Gravelly Silt Loam. This is a strongly acid and well-drained but water retentive soil. It is responsive to good management, and fertilization with lime, phosphorus and (usually) potash.

At Dundee - Volusia Stony Silt Loam. This is a somewhat poorly drained and strongly acid soil. It is of low natural fertility and needs heavy liming and fertilization; it can be adapted for corn, small grains, and hay exclusive of alfalfa.

At Penn Yan - Ontario Fine Sandy Loam. This is a high lime, well-drained soil. It is usually associated with rolling topography and subject to erosion. Phosphorus is consistently deficient.

Experimental Procedure:

Crops: Four crops were included in the experiment - tomatoes, peas, sweet corn, and lima beans. Four treatments were considered: without irrigation or mulching, with irrigation alone, with mulching alone, and with both together.

Rainfall and Irrigation: One inch of water was applied when soil water dropped to 50% of capacity.

	1954	1955
	(inches)	
Ithaca		
Rainfall, June - Sept.	9.4	11.0
Irrigation	6.0	8.6
Total	15.4	19.6
Number of applications	6	8
Dundee		
Rainfall, June - Sept.	8.0	9.6
Irrigation	2.2	7.0
Total	10.2	16.6
Number of applications	2	7
Penn Yan		
Rainfall, June - Sept.	8.5	8.0
Irrigation	3.2	7.0
Total	11.7	15.0
Number of applications	3	7

Results:

Quality Change: No observed difference.

Yield Per Acre:

	1954	1955
	(tons per acre)	
Ithaca		
With irrigation	33.9	23.3
Without irrigation	13.0	11.0
Increase due to irrigation	20.9	12.3
Percentage increase	161%	112%

	1954	1955
	(tons per acre)	
Dundee		
With irrigation	4.0	19.4
Without irrigation	3.5	9.7
Increase due to irrigation	0.5	9.7
Percentage increase	14%	100%
Penn Yan		
With irrigation	14.6	11.1
Without irrigation	11.0	5.8
Increase due to irrigation	3.6	5.3
Percentage increase	33%	91%

3. SUMMARY OF ITHACA STATION WORK (1955-57)

Source of Data: Pratt, A.J., "Effect of Irrigation and Mulch on the Yield and Quality of Tomatoes" (Snap Beans and Radishes), a cooperative experiment conducted by the Departments of Vegetable Crops and Agricultural Engineering at Cornell University, 1955-57 inclusive, Mimeo Reports, Department of Vegetable Crops.

Time: 1955-57

Location: Ithaca, New York.

Soils: Chenango Gravelly Silt Loam. This is a strongly acid and well-drained but water-retentive soil. It is responsive to good management and fertilization with lime, phosphorus and (usually) potash.

Experimental Procedure: Four treatments - without irrigation or mulching, and with irrigation and mulching separately and together - replicated three times.

Rainfall and Irrigation: The plots were irrigated to field capacity when plants had used 50% of "available" water at the 6 and 12 inch levels.

	1955	1956	1957
		(inches)	
Rainfall, June - Sept.	11.0	14.2	11.7
Irrigation	8.6	3.0	6.4
Total	19.6	17.2	18.1
Number of applications	----	3	7

Fertilizer: 1500 pounds of 5-10-10 were applied per acre ($38 worth at 1956 prices).

Spacing: Three feet by five feet.

Varieties: Long Red (1955), Moreton Hybrid (1956), and Moreton Hybrid and 54179 - Munger (1957).

Results:

Quality: Irrigated tomatoes tended to be of better quality. Cracking of tomatoes was prevalent on both irrigated and non-irrigated plots, but there was no significant difference in percentage cracked between plots.

Marketable Yield per Acre:

	Irrigated	Non-irrigated	Increase	Per cent increase
	(tons per acre)			
1955	34	15	19	127
1956	34	35	-1	-3
1957				
Moreton hybrid	52	46	8	17
54179 Munger	38	32	6	19
Three year "weighted" average	38	30	8	27

Maturity Dates: The irrigated crop matured earlier in 1955 owing to the beneficial effect of irrigation at the time of planting, when conditions were very dry.

COMPARABILITY OF RESEARCH RESULTS WITH FARMER EXPERIENCE

Tomatoes for fresh market, New York	1949-54 average	1954	1955	1956	1957
Acres	8,550	7,200	7,000	6,400	5,100
Yield, tons per acre	6.1	6.1	5.3	4.8	6.0
Price per ton	$82.00	$82.80	$96.00	$99.00	$97.00

Source: Vegetables for Fresh Market, Annual Summaries, A.M.S., U.S.D.A.

Note: Average "no irrigation" yields on the experimental plots at Ithaca were 5 times as high as average on-farm yields.

FACTORS DETERMINING IRRIGATION COSTS AND RETURNS

Irrigation whether beneficial or not costs money. This section discusses the relationship between the additional costs resulting from irrigation and added returns that result or are necessary. The discussion is presented in general terms only. It is followed by an assessment of the profitability of irrigation on particular crops in New York State as revealed from the results of the experiments summarized in the previous section.

Irrigation is most likely to be a paying proposition for farmers in a dry area with good soils where irrigation water is readily available. Because average growing season rainfall in New York is adequate for many crops and because some of the soils on most farms are imperfectly drained, irrigation can not be recommended as a practice on all farms. While irrigation may prove to be profitable for some crops in some areas of the state, its use may never become as general as in the irrigated valleys of the Western United States.

Benefits

The "physical" benefits to be gained from using irrigation are generally associated with:

(1) increased crop yields
(2) greater yield regularity from year to year
(3) improved quality.

Each of these changes may be measured; once measured they should be evaluated in money terms and compared with the cost of achieving them.

It is easy to value increased production of unchanged quality, but where quality changes take place, the value of increased output is more difficult to determine. This statement applies particularly to the production of experimental plots not sold on the market.

Costs

Costs of irrigation in New York State have been discussed more fully elsewhere:

(1) Stanton, B.F., "Operating Costs for Irrigating Equipment, Western New York", A.E. 1061, Department of Agricultural Economics, Cornell University, May 1957.

(2) Rogalla, J.A., "Factors Affecting Irrigation Labor Efficiency in Western New York", M.S. Thesis, Department of Agricultural Economics, Cornell University, September 1958.

A few general points about the costs of owning and operating an irrigation system and results which may be expected are in order:

(1) Installing any irrigation system involves a large amount of capital, larger than that required for most other new pieces of equipment. (That is, if a system of "economic size" is bought; systems that are "too small" have high costs per acre.)

(2) The introduction of irrigation means a change in one's system of farming. Many more new techniques (skills) have to be learned than if a hay-baler, or combine, for instance, is introduced into the farm business.

(3) Unlike other intensive capital changes, irrigation requires more labor, not less. This labor is required in the busy summer season when it is least available.

(4) Certain additional costs per acre may be involved when irrigating - fertilizer and fungicides. More fertilizer should not, however, be applied unless the additional cost is covered by added returns.

(5) Delayed crop maturity through irrigation may limit yield increases. For example, the proportion of green fruits is greater on irrigated tomatoes at the end of the season than for non-irrigated tomatoes. Most crops are not, however, adversely affected.

(6) Irrigation, through increasing total output, may lead in total to some price declines. The price of cabbage is highly sensitive to changes in production, whereas tomato and snap bean prices remain much more steady from year to year.

Economic Assessment of Experimental Results

The experiments which have been summarized cover a few crops only. These crops are in most cases, however, the most important of the high value crops grown in the state. Although it would be desirable to have information on the yield response to irrigation for all commercial crops in New York State, knowing what to expect from irrigation on a few major crops will provide some indication to a farmer of whether or not an irrigation system is warranted on his own farm.

Not covering all the crops that a farmer might consider irrigating is less of a weakness of the experimental work to date than the fact that the experiments have been confined to a few locations only. Both Geneva and Ithaca have a higher growing season rainfall than the parts of the state where the bulk of these crops are grown. Still, if it can be shown that irrigation seems to be a paying proposition at either of these locations, there is strong likelihood that irrigation can be quite profitable in important areas of Western New York. And even if the experimental results at Geneva or Ithaca suggest that irrigation of certain crops does not pay, such conclusions may not be true for other areas.

Still more difficulties in interpretation arise from the soil types on which the experimental crops were grown. Some soils "need" irrigation more than others, and yield response to irrigation may be quite different on soils other than those used for the experiments summarized above.

In addition, every farm is unique and irrigation costs and returns will vary for each farm. Before an irrigation system is installed on any farm, the conditions peculiar to that farm must be taken into account - its rainfall (amount and variability), its soils, its water supply, terrain and so on.

Procedures Used

The profitability of irrigation on the various experimental crops is assessed against two cost levels. The two cost levels chosen have been developed from survey data, and may be taken to represent "efficient" and "high cost" irrigation systems respectively.

Costs

Total costs of irrigation can be conveniently classified as fixed and variable. Fixed costs are those which are incurred year by year regardless of how much the system is used, i.e., interest on capital invested, depreciation,1/ insurance, and storage. Variable costs are incurred whenever the system is used, and include power and fuel, labor, repairs, water, and machine expenses.

The two cost levels chosen as a basis for comparison with the value of yield increment figures are:

Low Cost	Fixed costs	\$10 per acre per year
	Variable costs	\$ 3 per acre-inch of water applied
High Cost	Fixed costs	\$15 per acre per year
	Variable costs	\$ 5 per acre-inch of water applied

For instance, if no water were used, annual costs per acre would be \$10 and \$15 respectively for the low and high cost operators. If three inches of water per acre are applied, the total annual costs would be \$10 + \$9 = \$19 and \$15 + \$15 = \$30 per acre per year, respectively.

Valuing the Increase in Yield

Not all the value of the increased production resulting from irrigation can be treated as net gain. The additional output resulting from irrigation involves added harvesting and marketing costs. In the case of tomatoes for processing for instance the sale value per ton is \$30, but the harvesting and marketing costs are approximately \$10 per ton, leaving an "on farm" value of \$20 per ton. This \$20 "on farm" return is then available to meet the irrigation (and other) costs that have been incurred in the production of this higher yield per acre.

In the discussion which follows all yield increases have been valued using the "on farm" basis.

1/ Strictly speaking only depreciation from obsolescence should be included as a fixed cost, but it is more convenient to class all depreciation as a fixed cost.

PROFITABILITY OF IRRIGATION

APPLES I, (p. 3)

Value of Yield Increase: 158 bushels of Golden Delicious per acre at $1.50 to $2.00 "on farm" value per bushel, or $237 to $316 per acre.

Cost of Required Irrigation: Twelve inches of water were applied to get this yield response. The annual per acre cost of this water was $46 and $75 per acre respectively for "low cost" and "high cost" irrigation.

Profitability: This single experimental observation suggests that irrigation of apples may be a profitable proposition on shallow soils in a dry year.

Quality Change: The favorable yield response is associated with definite quality improvement, suggesting an even greater margin in favor of apple irrigation.

SNAP BEANS FOR FRESH MARKET, (p. 4)

Value of Yield Increase: Average annual increase in production was 2.7 tons per acre over the three year period 1955-57 at Ithaca. The "on-farm" value of this increased production was $216 per year (at $80 approximately per ton).

If the percentage response recorded in the Ithaca experiment - 42% - is applied to the 1955-57 state average yield per acre, 1.7 tons, the expected yield increase from irrigation would be 0.7 tons with an "on farm" value of $56 approximately per year.

Cost of Required Irrigation: The annual average per acre costs were $28 and $45 respectively for the "low cost" and "high cost" systems. From 3.0 to 8.6 inches of water were applied in the three years covered.

Profitability: Irrigation of fresh market snap beans under these conditions would therefore seem to be a paying proposition over a period of years.

Quality Change: Irrigation may also lead to a high price per ton for beans because of increased uniformity and straightness of pods.

CABBAGE FOR PROCESSING, (p. 6)

Value of Yield Increase: Average annual increases in production from irrigation were 3.0 tons and 4.7 tons per acre for the 24 inch and 12 inch spacing respectively for the Geneva cabbage experiment for the years 1952-55. The "on-farm" value of this increased production was $30 and $47 respectively per year (at $10 a ton).

Cost of Required Irrigation; The annual average costs per acre were $23 and $36 respectively for the "low cost" and "high cost" systems. From 3.7 to 4.9 inches of water per year were applied in the four years 1952-55. The range in annual costs was $21 to $25 and $33 to $40 for the "low cost" and "high cost" systems respectively.

Profitability: Irrigation of cabbage for processing may be a paying proposition, but it is certainly not highly profitable. It should be remembered that average experimental yields were 80% above state average.

The net effect of irrigation on quality was small.

SWEET CORN FOR PROCESSING, (p. 8)

Value of Yield Increase: A total of 6.3 tons increase in yield resulted from irrigation over the five year period. At an "on farm" value of $16 per ton the additional return per acre over the five year period was $101, or $20 per year.

Cost of Required Irrigation: Annual average per acre costs of irrigation were $20 and $32 respectively for "low cost" and "high cost" systems.

Profitability: Irrigation of sweet corn for processing would seem to be profitable only under drier conditions than occurred at Geneva. It should be remembered that the average yields under experimental conditions, and thus yield increases, have been higher than those obtained under field conditions.

SWEET CORN FOR FRESH MARKET, (p. 10)

Value of Yield Increase: The per acre yield of sweet corn at Ithaca (1954-55), Dundee (1954-55), and Penn Yan (1955 only) increased by a weighted average of 38%. Applying this (very rough) average yield increase to the state average yield, 2.9 tons per acre in both years for fresh market corn, would mean an increase due to irrigation of 1.1 tons per acre per year. The "on farm" value of this yield increase would be approximately $50.

Cost of Required Irrigation: Annual average per acre costs of irrigation were $28 and $46 respectively. (Again a rough weighted average for the three locations has been used.)

Profitability: Computed on this basis the irrigation of even fresh market sweet corn will not always be profitable. The profitability of irrigating sweet corn does, however, vary from location to location - while it may never be profitable to irrigate sweet corn on the Volusia Stony Silt Loam at Dundee, it might prove quite profitable on better soils and in areas with less rainfall during the growing season.

PEAS FOR PROCESSING, (p. 13)

Value of Yield Increase: The average (absolute) per acre increase in yield recorded at Geneva for 1952-55, 1957 was 740 pounds, or an increase of 19%. The "on farm" value of this yield increase is approximately $30. If this percentage yield increase were applied to the state average yield for the same period, the value of yield increase would be about $15 only.

Cost of Required Irrigation: Average annual irrigation costs were $18 and $32 per acre for "low cost" and "high cost" systems respectively. From 1.8 to 5.1 inches of water, with an annual average of 2.7 inches per acre, were applied in the five years 1952-55, 1957.

Profitability: The irrigation of peas for processing is only profitable if irrigation costs are low under Geneva conditions.

PEAS FOR FRESH MARKET, (p. 15)

A 39% (rough weighted average, see Sweet Corn for Fresh Market) increase in yield was recorded for peas at Ithaca, Dundee, and Penn Yan for 1954-55. The "on farm" value of this yield increase, at processing prices, is $31 when applied to state average yield. With a yield response of 39% irrigation of peas for fresh market is likely to be a paying proposition.

POTATOES I, (p. 17)

Value of Yield Increase: The average percentage increase in yield due to irrigation in the Long Island experiments was 22% for the eight years 1938-45 inclusive. These percentage yield increases varied from minus 8% (1942) to plus 141% (1939). The average absolute yield increase was 50 bushels per acre, with an "on farm" value of $37. (The percentage yield increase recorded in the experiment has been applied to the 1936-45 average yields for Long Island as a whole to give the 50 bushel figure.)

Cost of Required Irrigation: The bulletin reports that an average of 4.2 inches of irrigation water were applied each year. The average annual costs per acre were therefore $22 and $36 for "low cost" and "high cost" operators respectively.

Profitability: Even though the "value of yield increase" has been calculated conservatively it is still sufficient to cover both levels of estimated irrigation costs. Quality improvement would also contribute to net profitability.

POTATOES II, (p. 19)

Value of Yield Increase:

(a) Genesee County, 1949-51. Average annual increase in "on farm" value of potato production per acre was $43.

(b) Onondaga County, 1950-51. Average "on farm" value of annual increase per acre was $46.

(c) Tompkins County, 1951 only. The increased production had an "on farm" value of $50.

Cost of Required Irrigation:

(a) Genesee County, 1949-51. Average annual per acre irrigation costs were \$21 and \$33 for the "low cost" and "high cost" operators respectively.

(b) Onondaga County, 1950-51. Average annual irrigation costs per acre on the two bases were \$18 and \$28 respectively.

(c) Tompkins County, 1951 only. The per acre irrigation cost on each basis was \$16 and \$25 respectively.

Profitability: In each location, and at both cost levels, the value of the increased production of potatoes was more than sufficient to meet the annual irrigation costs.

POTATOES III, (p. 23)

Value of Yield Increase: The average maximum percentage yield increase from irrigation for 1949-51 was 32%; the average minimum percentage increase was 20%. Applying these percentages to the average per acre production on Long Island for the same three years we get annual increases from irrigation of 96 bushels and 60 bushels per acre respectively. The "on farm" value of these increases is \$72 and \$45 per acre.

Cost of Required Irrigation: An average of $7\frac{1}{2}$ inches of water per year was applied for both the maximum and minimum yield increments in each year (see above, p. 18 for details of how much water was applied to each plot). The cost of this added water was \$33 and \$53 respectively per year for "low cost" and "high cost" operators.

Profitability: Irrigation is thus shown to be profitable in every case except when there is "minimum response" for a "high cost" operator.

TOMATOES FOR PROCESSING, (p. 25)

Value of Yield Increase:

(a) Red Jacket, Normal fertility, 1953-57. Average annual yield increase per acre due to irrigation was 4.1 tons. On a percentage basis this was an increase of 46% per year. The "on farm" value of this (absolute) yield increase was \$86 per acre per year.

(b) Geneva 11, Normal fertility, 1954-57. Average annual yield increase per acre from irrigation was 5.0 tons. On a percentage basis this was an increase of 52% per year. The "on farm" value of this (absolute) yield increase was \$105 per acre per year.

Note: Average experimental yields per acre for both varieties with normal fertility are very close to state average yields.

Cost of Required Irrigation:

(a) Red Jacket, 1953-57. Average annual per acre irrigation costs were $26 and $42 for the "low cost" and "high cost" operators respectively. From 1.4 to 9.9 inches of water, with an annual average of 5.6 inches per acre, were applied in the five years, 1953-57.

(b) Geneva 11, 1954-57. Average annual per acre irrigation costs were $27 and $43, for the "low cost" and "high cost" operators respectively. From 1.4 to 9.9 inches of water, with an annual average of 5.9 inches per acre, were applied in the four years, 1954-57.

Profitability: It has been shown, therefore, for both varieties that irrigation more than pays for itself.

TOMATOES FOR FRESH MARKET, (p. 28)

Value of Yield Increase: The average percentage yield increases for the three locations taken together for 1954 and 1955 were 69% and 101% respectively.

(The comparable increases at Geneva for the same variety, Long Red, for the years 1954 and 1955 were 60% and 111% respectively.) Applying these percentage increases to the state average yield for 1954 and 1955, 8.3 tons per acre in both years, shows that irrigation of tomatoes would lead to a yield increase of 5.4 and 8.7 tons per acre. The net "on farm" value of these (scaled down) increases is $113 and $183 respectively or a two-year average increase of $148.1/

Cost of Required Irrigation: Average annual costs of irrigation for the two years were $28 and $45 for the "low cost" and "high cost" systems respectively.

Profitability: Irrigation may not be as profitable as it was in 1954 and 1955 very often, but the yield increases of these two years are sufficient to cover annual irrigation costs of 5 to 8 years with no further yield increments from irrigation.

CONCLUSIONS

Although these experimental results cannot provide conclusive evidence on the profitability of irrigating given crops, they do show that irrigation is likely to be more profitable on some crops than others. It must be remembered that the assessment of profitability is based on the assumption that the irrigation system will be bought primarily for use on the given crop. Where an irrigation system is bought for irrigating a crop where irrigation is known to be profitable, and water is diverted when available to other, less profitable crops, then this supplementary irrigation might also pay.

1/ Note: Cost of additional fertilizer not included.

The six vegetable crops considered may be ranked in the following order of irrigation profitability:

(LIKELY TO BE PROFITABLE IN MOST YEARS
- HIGHLY PROFITABLE IN DROUGHT YEARS)

Tomatoes - consistent pattern of yield increases at different localities.
Potatoes

(MEDIUM TO LOW PROFITABILITY)

Cabbage - irrigation of fresh market cabbage more likely to be profitable.
Sweet corn for fresh market
Peas - irrigation of both fresh market and processing varieties is likely to be profitable, but not highly so, over a period of years. A shallow rooted crop.

(UNLIKELY TO BE PROFITABLE IN MOST YEARS)

Sweet corn for processing
Snap beans for processing

The spectacular yield increase recorded for the irrigation of apples under somewhat unusual conditions, does not seem sufficient for any general conclusions to be drawn regarding the profitability of irrigating this crop.

The use of irrigation systems has shown a dramatic increase in New York State in the past decade. Experimental results suggest that there is still scope for further increases in the use of irrigation
(a) on certain crops
(b) if costs can be kept to a reasonable level.

The fact that the demand for high value crops of excellent quality continues to rise means that irrigation is likely to expand in New York where water is available and growing season rainfall is often short.