BULLETIN No. 276 JUNE 1950

VALUE of IRRIGATION with DIFFERENT FERTILITY TREATMENTS for VEGETABLE CROPS

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FIRST PRINTING 4M, JUNE 1950.

VALUE of IRRIGATION with DIFFERENT FERTILITY TREATMENTS for VEGETABLE CROPS

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PRESENTED in this bulletin are the results of studies extending over 11 years. While designed primarily as an irrigation experiment, the investigation included studies of the independent and combined effects of irrigation, organic materials, and fertilizer rates on the yield, grade, and relative economic value of vegetable crops.

IRRIGATION RESEARCH

A survey of the literature reveals a large number of publications on irrigation. Much of the work in America has been done in the western states. A considerable amount of the literature is concerned with techniques and equipment relating to application of irrigation water by a number of different methods. Literature is especially abundant in formulas, tables, and instructions dealing with capacity of pumps, pipes, canals, and flumes; with loss of pressures, or head, as affected by size and length of pipe; and with movement and absorption of water by soils of different textures and depths. These have been reviewed by a number of writers *(1, 7, 19)* and are the subjects of a number of popular publications *(13, 18)*.

The amount of research on crop response and irrigation requirements of different crops in humid areas is somewhat limited. A review of published research and other reports dealing with

supplemental irrigation is given in Johns-Manville "Manual on Supplemental Irrigation" *(1)*. Gaines and others *(7)* have prepared a rather complete bibliography on this and related subjects. Stallings *(19)*, in serial releases by the Soil Conservation Service, "Abstracts of Recently Published Materials on Soil and Water Conservation," has reviewed current literature on irrigation. A very recent survey has been made of current research in the Southeast by a committee of the Southeastern Section, American Society of Agricultural Engineers *(26)*. A number of textbooks are available on irrigation and related topics *(8, 11, 12, 14, 25)*.

A limited amount of research has been conducted in the South on irrigation of vegetable crops. The studies generally have been confined to measurements of crop yields with and without irrigation. Some studies have dealt with other effects.

Data showing increases from irrigation have been published by the agricultural experiment stations of Georgia *(3, 4)*, Tennessee *(20, 21, 22, 23)* and Oklahoma *(2)*, and by the Tennessee Valley Authority *(1)*.

Nettles and others *(15)* of Florida studied the effects of different types of irrigation and of different nitrogen rates on the yield and quality of cabbage and beans. Irrigation affected yields only to a minor extent one year, whereas in another year yields were markedly affected.

Janes *(9)* of Florida studied the effects of three types of irrigation on the composition of two bean varieties. Irrigation was found to reduce the percentage composition of most of the 17 constituents studied.

Cordner *(6)*, working with sweet corn and tomatoes in Oklahoma, concluded that yields could be substantially increased by a few timely irrigations. Set of tomatoes and blossom-end rot were reduced, but other rots were increased by irrigation.

Strand *(22, 23)* in the Douglas Reservoir Area of Tennessee obtained from irrigation increases in yield of cabbage of 7.3 tons per acre with 600 pounds per acre of fertilizer, 8.3 tons with 900 pounds of fertilizer, and 8.5 tons with 1,200 pounds of fertilizer. Also, irrigation gave very marked increases in the yield of beans.

Earlier reports have been made of certain phases of this investigation *(28, 29)*.

RAINFALL AND OTHER CLIMATIC FACTORS OF ALABAMA

AVERAGE RAINFALL BY SECTIONS AND PERIODS

The average annual rainfall in the southeastern states ranges from 40 to 60 inches; in Alabama, Georgia, Florida, South Carolina, Tennessee, and Mississippi, the average is about 50 inches.

In Table 1 is given the average annual rainfall by months in Alabama for the 53-year period, 1886 to 1938 *(10)*. The average for the State in that period was 53 inches; for the spring season, it was 14.23 inches; for the summer, 14.34 inches; for the fall, 9.30 inches; and for the winter, 15.12 inches. The amount of rainfall varies by locations within the State. During a 27-year period, the average annual rainfall was 57 inches at Robertsdale, and during a 39-year period, it was 49 inches at Tuskegee.

In Figure 1 is given the average rainfall by 10-day periods for five belts of the State for a period of 20 to 25 years. The graph shows that for the periods covered the average rainfall for each of the five parallel belts has been relatively low in October, November, and also low during the last 10 days of August and the first 20 days of September. Rainfall during the month of July and the first 20 days of August has been above

TABLE 1. PRECIPITATION, EVAPORATION, AND EVAPO-PRECIPITATION RATIOS BY MONTHS, AUBURN, ALABAMA

Month	Precipitation[1]	Evaporation[2]	Evapo-precipitation
	Inches	*Inches*	*Ratio*
January	4.98	1.41	0.28
February	5.24	2.42	0.46
March	5.86	2.86	0.49
April	4.49	3.82	0.85
May	3.88	5.63	1.45
June	4.24	6.55	1.54
July	5.49	6.08	1.11
August	4.62	5.86	1.27
September	3.28	4.67	1.42
October	2.79	3.71	1.33
November	3.24	2.35	0.73
December	4.90	1.63	0.33
TOTAL	53.01		

[1] Precipitation in inches equals the average rainfall by months for a 53-year period, 1886-1938.

[2] Parsons, D. A. Summary of principal results, Project AL-R-3, Auburn, Alabama, for calendar year 1947. Unpublished report, Soil Conservation Service, United States Department of Agriculture.

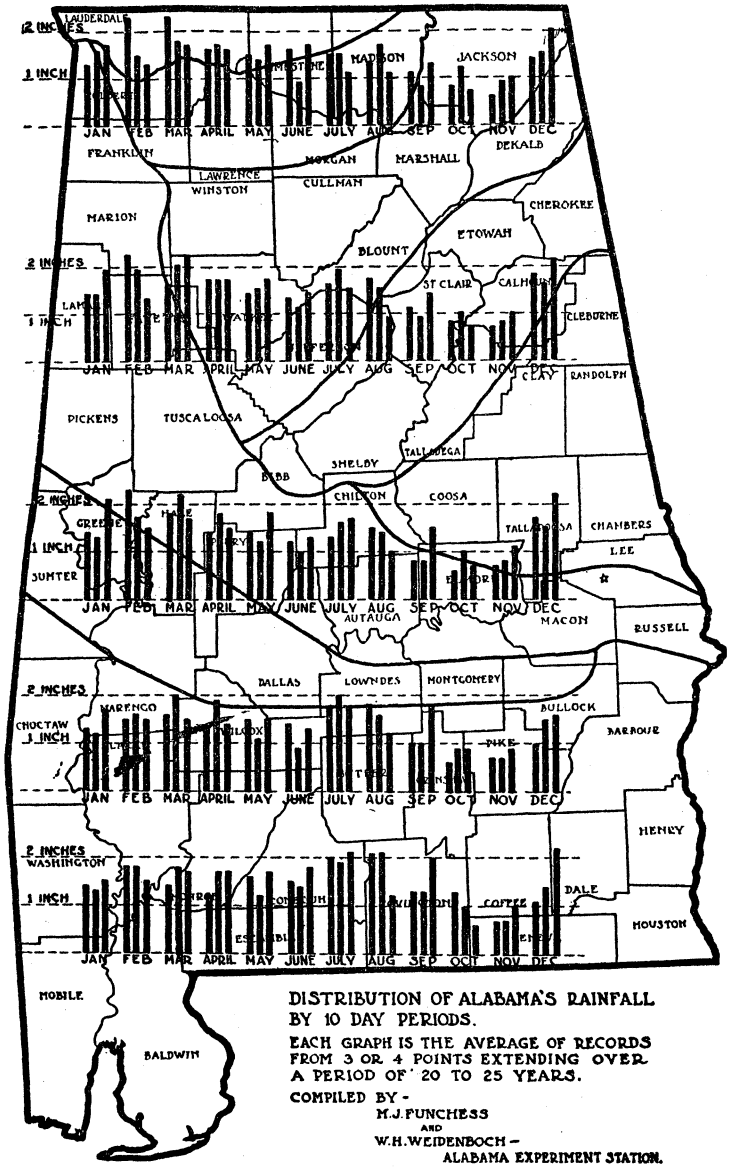


FIGURE 1. Distribution of rainfall in Alabama by 10-day periods.

the average. While these data give the periods when rainfall is likely to be high, average, or low, they do not assure rainfall at these periods for any one year.

Variations in Rainfall

Although the average rainfall in Alabama is about 53 inches, it is very irregular. The amount of rainfall varies from year to year. The highest average annual rainfall recorded for the State during the 53-year period was 76.5 in 1929; the lowest was 39.2 inches in 1904.

Between 1899 and 1938, rainfall for different sections of the State during the 10 wettest years ranged from 50 to 70 inches, while during the 10 driest years the range was 40 to 45 inches; rainfall for the 10 wettest summers ranged from 20 to 24 inches, whereas in the 10 driest summers the range was 8 to 12 inches.

Given in Table 2 is the number of times on a 50-year basis rainfall during 2-, 3-, and 4-week periods totaled less than one inch, less than three-fourths of an inch, and less than one-half of an inch for three periods of the year at three locations in the State. The data are based on records for 42 years at Cullman, 56 years at Clanton, and 37 years at Robertsdale. All data have been converted to a 50-year basis. The data provide a table of odds on the probability of droughts for three sections of the State. For example, at Clanton in 50 years there were 52 times during the fall months, 27 times during the spring months, and 13 times during the summer months when rainfall was less than one inch for four consecutive weeks.

Evaporation and Evapo-Precipitation Ratios by Months

In Table 1 are given by months evaporation data from a floating pan at Auburn and the calculated evapo-precipitation ratios based on these data and the average rainfall of Alabama. The evaporation data were obtained by Parsons of the Soil Conservation Service.[1] The ratios exceeded 1.0 from May to October. High evaporation rates are associated with high water losses from soil surfaces and plants, while high ratios are associated with periods of likely moisture deficiency in the soil.

[1] Summary of principal results. Project ALR-3. Soil Cons. Serv. Unpublished Report. 1947.

TABLE 2. NUMBER OF TIMES DROUGHT PERIODS OF CERTAIN LENGTHS HAVE OCCURRED AT DIFFERENT LOCATIONS IN ALABAMA[1]

Number of continuous weeks	Total accumulated rainfall less than	Calculated number of times in 50 years rainfall less than indicated amounts for different periods of year[2]								
		Cullman			Clanton			Robertsdale		
		March April May	June July August	September October November	March April May	June July August	September October November	March April May	June July August	September October November
	Inches									
Two weeks	1	117	126	169	135	131	186	127	63	154
	¾	93	102	144	115	101	164	101	51	139
	½	68	69	118	92	74	140	84	41	120
Three weeks	1	54	49	87	56	40	89	47	16	84
	¾	37	32	67	44	28	80	39	14	72
	½	18	18	48	31	20	57	24	7	55
Four weeks or more	1	18	23	45	27	13	52	23	8	45
	¾	8	12	31	19	11	44	18	7	29
	½	4	5	24	14	4	29	8	4	23

[1] Data prepared by Montgomery office, Weather Bureau, U. S. Department of Commerce.

[2] Drought frequencies calculated on a 50-year basis from actual records of 42 years at Cullman, 1907-48; 56 years at Clanton, 1893-1948; and 37 years at Robertsdale, 1912-48.

METHODS AND PROCEDURES

The studies reported in this publication involved two phases. The first phase consisted of a study of effects of irrigation, fertilizers, and organic materials on the yield and grade of different vegetable crops. The second phase consisted of a study of production costs and returns from crops under irrigation using the best combination of treatments found in the first phase of the experiment.

The first phase was conducted in concrete field bins filled with local soils thoroughly composited among all bins and within each bin *(27)*. Phase one consisted of Series A and Series B. Series A was started in 1938 and Series B was begun in 1940.

Treatments in the two series of phase one are given in the following tables:

SERIES A

Pounds per acre	*Treatment*
0	No treatment (check).
500	6-10-4; fertilizer grade from 1938 through 1942 was 6-8-4; in 1943 and subsequent years the grade was 6-10-4. The quantity shown under "pounds per acre" is the amount applied to each crop in the succession.
500	6-10-4 + irrigation; 1 inch of water per week was applied when rainfall during previous week had not supplied that amount and plants and soil indicated need for water; measured amount equal to 1 inch of water was applied through a porous hose; water for irrigation was obtained from city supply.
500	6-10-4 + organic materials; organic materials consisted of 3 tons per acre of dry lespedeza sericea applied to each of three crops per year in 1938 and 1939, and after 1939, 2 tons per acre of dry lespedeza sericea applied in winter and 6 tons of green crotalaria in summer.
500	6-10-4 + organic materials + irrigation.
1,000	6-10-4.
1,000	6-10-4 + irrigation.
1,000	6-10-4 + organic materials.
1,000	6-10-4 + organic materials + irrigation.
1,000	6-10-4 + vetch grown and turned + irrigation.
1,000	6-10-4 + cowpeas grown and turned + irrigation.
1,000	0-10-4 + organic materials + irrigation.
1,000	10-10-4 + irrigation.

SERIES B

Pounds per acre	*Treatment*
0	No treatment (check).
1,000	6-10-4; the quantity shown under "pounds per acre" for each treatment was applied to each of two crops per year.
1,000	6-10-4 + irrigation; 1 inch of water per week was applied when rainfall during previous week had not supplied that amount and plants and soil indicated need for water; a measured amount equal to 1 inch of water was applied through a porous hose; water for irrigation was pumped from a well.
1,000	6-10-4 + 12 tons manure.
1,000	6-10-4 + 12 tons manure + irrigation.
1,000	6-10-4 + vetch; vetch was grown on plots and turned.
1,000	6-10-4 + vetch + irrigation.
1,000	6-10-4 + rye; rye was grown on plots and turned.
1,000	6-10-4 + rye + irrigation.
1,000	6-10-4 + 12 tons manure + vetch.
1,000	6-10-4 + 12 tons manure + vetch + irrigation.
1,000	6-10-4 + 12 tons manure + vetch + irrigation; minor elements were applied to all treatments except this one.
1,000	6-10-4 + 6 tons manure + vetch + irrigation.
1,000	6-10-4 + 6 tons manure + rye + irrigation.
1,500	6-10-4 + 12 tons manure + vetch + irrigation.
2,000	6-10-4 + 12 tons manure + vetch + irrigation.

The economic studies were conducted on field areas large enough to measure costs of applying the several treatments and of obtaining representative data on costs, labor requirements, and returns. The water supply was a farm pond. A portable system was used to apply the water. Standard treatments consisted of 1,500 pounds per acre of a 6-8-4 fertilizer, plus a side application of 250 to 325 pounds of nitrate of soda applied to each crop, and 12 tons of manure applied annually. Two successive crops were grown each year; one-half of the cost of manure was charged to each.

The irrigation system for the economic study consisted of a rebuilt auto motor, a centrifugal pump with capacity of 180 gallons per minute, 416 feet each of main and lateral pipe of light galvanized metal, and 10 overhead whirling sprinklers, each having a capacity of 18 gallons per minute.

PRESENTATION OF DATA

CHARACTERISTICS OF THE SOILS

In Table 3 are given the moisture equivalent, wilting percentage, maximum available moisture percentage, and approximate available moisture capacity of each of the first 3 feet of the soils used in the studies. The method of Briggs and McLane *(5)* was used in obtaining moisture equivalent, while that of Richards and Weaver *(17)* was used in determining wilting percentage.

TABLE 3. MOISTURE EQUIVALENT, WILTING PERCENTAGE, AND APPROXIMATE AVAILABLE MOISTURE CAPACITY OF SOILS USED

Source of sample	Depth	Moisture equivalent	Wilting percentage	Maximum available moisture	Approximate available moisture capacity
	Feet	*Per cent*	*Per cent*	*Per cent*	*Inches*
Series A	0 to 1	9.44	3.64	5.80	1.06
	1 to 2	18.39	10.16	8.23	1.38
	2 to 3	20.16	11.10	9.06	1.41
Series B	0 to 1	7.73	2.81	4.92	0.90
	1 to 2	11.63	6.09	5.54	0.93
	2 to 3	12.97	7.45	5.52	0.86
Field area	0 to 1	9.12	2.83	6.29	1.15
	1 to 2	11.88	5.50	6.38	1.07
	2 to 3	15.59	8.88	6.71	1.05

All soils were rather low in available moisture capacity. The soil used in Series A had a somewhat higher capacity than those used in Series B and in the field plots. The soil in Series B was especially low in available moisture capacity in the lower 2 feet, being able to hold only about 2.69 inches of available water in the upper 3 feet. On the other hand the soil in Series A could hold about 3.85 inches and that in field plots 3.27 inches in the upper 3 feet.

RAINFALL DATA FOR YEARS OF EXPERIMENT

In Appendix Table 1 are given the amounts of rainfall at Auburn by semi-monthly periods for the years covered by the irrigation experiment.

To provide sufficient water at critical periods for maximum or near-maximum yields, rainfall should be approximately 2 inches or more each semi-monthly period. The data reveal how irregular

rainfall was during the investigation. Between March 16 and April 15, 1938, there was a total of 14.45 inches of rainfall, or 25 per cent of a year's supply. During the next 9 weeks, April 16 to June 15, rainfall totaled only 5.83 inches; and from August 16 to November 15, over 13 weeks, the total was only 3.42 inches. Prolonged periods of low rainfall occurred in the fall of 1939, late summer and early fall of 1940, spring of 1941, late spring and summer of 1944, fall of 1947, and spring of 1948. Shorter or less severe periods of low rainfall occurred in the spring of 1940, summer and fall of 1943, and fall of 1944. The relation of prolonged periods of drought to response to irrigation will be observed in data presented later.

Effects of Irrigation in Different Years and Seasons

In Figure 2 are shown the increases and decreases in yield resulting from irrigation of a number of crops for years of high and low response. It may be seen that in some years benefits from irrigation were very pronounced, while in other years benefits were very small or even negative.

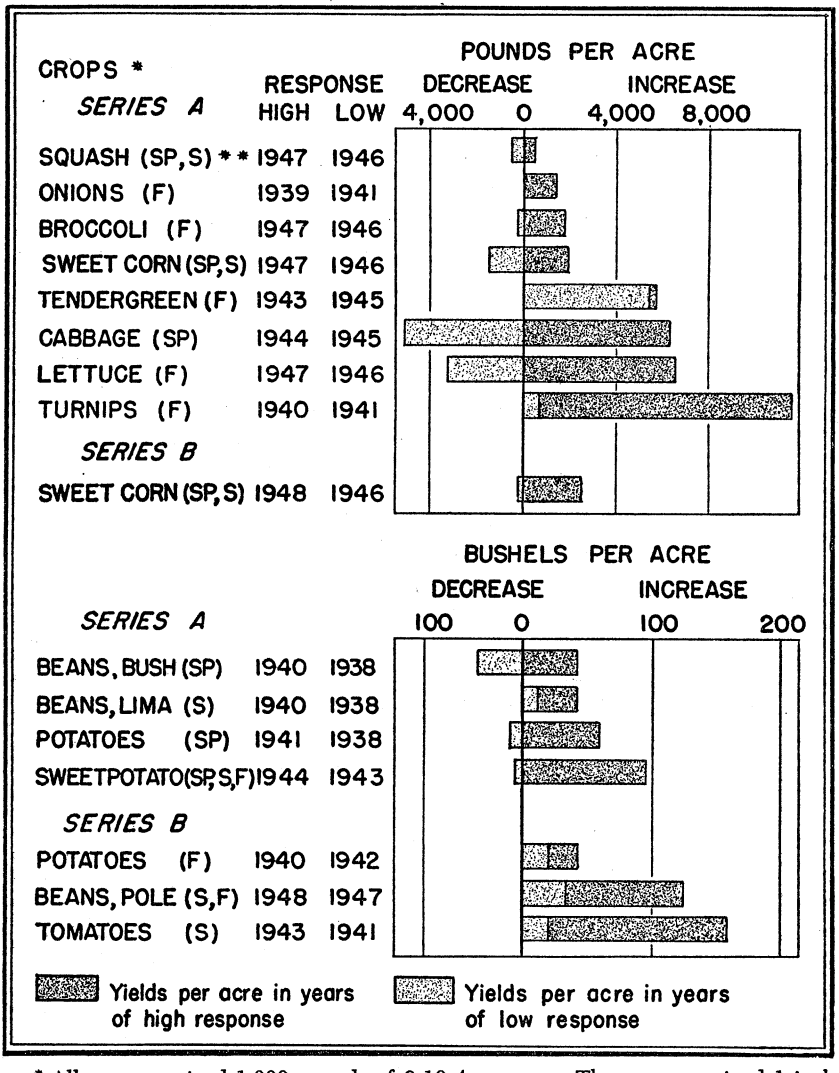
Effects of Irrigation as Influenced by Amount and Distribution of Rainfall

Of the factors that would be expected to account for differences in response of crops to irrigation in different years, the amount and the distribution of rainfall during the growing period should be of high importance.

In Appendix Tables 2 and 3 are given by years the actual and percentage increases in yield of crops and the amount and distribution of rainfall during four periods of growth. The rainfall data include the period from one week before planting to within one week of final harvest. The four periods were equal in length and corresponded roughly to: germination and establishment of stand, early growth, later rapid growth, and final growth and maturity. The data do not reveal a very close relationship between total rainfall and response to irrigation for a given period. There is a much closer relationship between distribution of rainfall and response to irrigation.

Data showing response to irrigation of a few crops receiving rainfall differing in amount and distribution are given in Table 4. The average rainfall for the four growing periods of cabbage was 1.84 inches per week in 1944 and also in 1945. Yet yields in 1944

were increased 6,099 pounds, while in 1945 they were decreased 4,890 pounds per acre by irrigation. The principal difference was in the distribution of rainfall, which was low in the fourth quarter of 1944, while low during the third period of 1945. In the case of



* All crops received 1,000 pounds of 6-10-4 per acre. The crops received 1 inch of water per week when rainfall the previous week had not supplied that amount and plants or soil indicated need of water.

** (SP) = spring, (S) = summer, (F) = fall.

FIGURE 2. Variations in response of crops to irrigation in different years.

TABLE 4. RELATION OF AMOUNT AND DISTRIBUTION OF RAINFALL AND RESPONSE TO IRRIGATION OF SELECTED CROPS

Crops[1]	Seasons	Years	Units	Increase or decrease from irrigation[2]		Rainfall per week				
						By period[3]				Av.
				Amount	Per cent	1st	2nd	3rd	4th	
						In.	*In.*	*In.*	*In.*	*In.*
Series A										
Beans, bush	Spring	1938	Bu.	—34	—17	1.06	3.75	0.66	0.88	1.59
		1940	Bu.	42	350	1.72	0.31	0.31	1.79	1.03
Cabbage	Spring	1944	Lb.	6,099	157	2.38	2.70	2.01	0.28	1.84
		1945	Lb.	—4,890	—26	2.86	1.23	0.43	2.82	1.84
Potatoes	Spring	1938	Bu.	—6	—3	0.51	1.91	2.43	1.06	1.48
		1941	Bu.	66	65	1.15	0.39	0.94	0.01	0.62
Turnip	Fall	1940	Lb.	11,505	395	0.39	0.12	0.02	1.00	0.38
		1941	Lb.	679	2	0.02	0.91	1.06	0.01	0.50
Series B										
Corn, sweet	Spring & sum.	1946	Doz.[4]	27	18	1.24	0.60	2.40	1.53	1.44
		1948	Doz.	413	103	0.32	0.32	0.47	1.76	0.72
Potatoes	Sum. & fall	1940	Bu.	48	171	0.92	0.27	0.08	0.95	0.56
		1942	Bu.	25	32	1.65	0.22	1.36	0.28	0.88

[1] All crops received 1,000 pounds of 6-10-4 fertilizer per acre.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] Each period was one-fourth of the time beginning one week before planting and extending to one week before final harvest.
[4] Sweet corn yields were measured in dozen ears per acre.

turnips, rainfall during the four periods in 1940 averaged 0.38 inches per week and in 1941, 0.50 inches; yet yields were increased by irrigation 11,505 pounds in 1940 and only 679 in 1941. Apparently crops reacted differently to lack of water at different periods; consequently, they reacted differently to irrigation at such times. Beans, and turnips apparently suffered most from low rainfall during the second and third periods, while cabbage suffered most from low rainfall during the fourth period, and potatoes during second and fourth periods. Cabbage in 1944 with an average rainfall for the four periods of 1.84 inches per week gave an increase from irrigation of 6,099 pounds per acre, while turnips in 1941 gave practically no increase with an average rainfall of only .50 inches per week.

Independent and Combined Effects from Use of Irrigation, Organic Materials, and Different Fertilizer Rates on Crop Yields

The data in Table 5 and Appendix Table 4 show increases in yield from irrigation, organic materials, and different fertilizer rates when used alone and in combinations.

In interpreting results, it should be emphasized that the responses measured are those resulting from use of certain practices with all related effects that those practices might have on productivity of soil or on effectiveness of the other practices used. For example, some of the organic materials used probably contained relatively large amounts of nitrogen. The effects of the organic materials, therefore, are not to be considered as the effects of organic matter *per se* but as the combined effects of the specific organic materials including the nitrogen and minerals as well as the carbonaceous materials they contained. Since no complete analyses were made of the organic materials, the specific amounts of nitrogen and other plant nutrients added cannot be enumerated. Therefore, the term "organic materials" is used in this report as a general, over-all expression.

The amount of nitrogen added in the organic materials and the effects of this nitrogen were considerable, as may be noted in the following table.

Treatments		
Fertilizer, 1000 pounds per acre	*Organic materials**	*Relative yield, average of six crops*
		Per cent
0-10-4	Standard	73
6-10-4	None	100
10-10-4	None	125
6-10-4	Standard	153

* Standard organic treatment, Series A, was 2 tons per acre of dried lespedeza sericea applied in late winter and 6 tons of green crotalaria in late summer.

It may be noted in the foregoing data that the standard organic materials with no commercial nitrogen added resulted in yields 73 per cent as high as yields from 60 pounds of nitrogen in the commercial fertilizer. One hundred pounds of commercial nitrogen gave a yield of 25 per cent above the yield from the 60 pounds in the 6-10-4 application. The combination of 60 pounds per acre of commercial nitrogen and the standard organic treatment resulted in a 53 per cent higher yield than that from the 60 pounds of commercial nitrogen without added organic materials. Thus, it

TABLE 5. AVERAGE YIELDS AND YIELD INCREASES BY SEASONS AND YEARS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND FERTILIZER RATES, SERIES A

Treatments		Yields and increases in yields per acre by seasons					
		Fall crops[2] all years			Spring crops[3] all years		
Fertilizer, 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[4]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Pounds		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
500	0	4,136	6,441	2,305	2,267	3,392	1,125
500	Standard	9,516	12,725	3,209	6,800	8,632	1,832
	Increase from organic materials	5,380	6,284	904	4,533	5,240	707
1,000	0	6,936	10,449	3,513	5,283	6,540	1,257
1,000	Standard	11,497	16,977	5,480	9,500	12,900	3,400
	Increase from organic materials	4,561	6,528	1,967	4,217	6,360	2,143
Increase from fertilizer without organic materials		2,800	4,008	1,208	3,016	3,148	132
Increase from fertilizer with organic materials		1,981	4,252	2,271	2,700	4,268	1,568

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] Fall crops consisted of broccoli, lettuce, tendergreen, and turnip.
[3] Spring crops consisted of beans, cabbage, and potatoes.
[4] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

TABLE 5. (*Continued*) AVERAGE YIELDS AND YIELD INCREASES BY SEASONS AND YEARS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND FERTILIZER RATES, SERIES A

Treatments		Yields and increases in yields per acre by seasons					
		Summer crops[2] all years			All crops all years		
Fertilizer, 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[3]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Pounds		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
500	0	4,289	5,320	1,031	3,551	4,947	1,396
500	Standard	8,461	9,127	666	8,206	9,945	1,739
	Increase from organic materials	4,172	3,807	—365	4,655	4,998	343
1,000	0	6,818	7,913	1,095	6,180	8,074	1,894
1,000	Standard	10,319	10,542	223	10,309	13,061	2,752
	Increase from organic materials	3,501	2,629	—872	4,129	4,987	858
Increase from fertilizer without organic materials		2,529	2,593	64	2,629	3,127	498
Increase from fertilizer with organic materials		1,858	1,415	—443	2,103	3,116	1,013

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] Summer crops consisted of corn, lima beans, squash, and sweetpotatoes.
[3] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

would appear that the nitrogen in the organic materials played a considerable role in the total effects of the organic materials.

INDEPENDENT EFFECTS OF IRRIGATION, ORGANIC MATERIALS, AND FERTILIZER RATES. The comparative effects of irrigation, organic materials, and fertilizer rates as independent factors may be noted in Appendix Table 4. When the effect of each practice was measured without the presence of either of the other two practices, all 12 crops in Series A produced yield increases from use of organic materials and from increased applications of fertilizers. These yield increases were obtained in years of high response as well as the average for all years. Similarly, yield increases were obtained with all 12 crops from use of irrigation for the years of high response, while, for the average of all years, 10 of the 12 crops produced increases in yields.

The relative effects of the three treatments for each season and for the average of all seasons for all years are shown in Table 5. Irrigation increased the average yield of the 12 crops for all years 1,396 pounds, organic materials increased the yield 4,655 pounds, while additional fertilizer increased the yield 2,629 pounds.

For the fall crops, including all years, irrigation increased the average yield 2,305 pounds, organic materials 5,380 pounds, and extra fertilizer 2,800 pounds per acre. For the spring crops (all years), the increases were 1,125 pounds from irrigation, 4,533 pounds from the organic materials, and 3,016 pounds from the extra fertilizer. In the case of summer crops (all years), the increases were 1,031 pounds from irrigation, 4,172 from organic materials, and 2,529 pounds per acre from the extra fertilizer.

In evaluating these results, it must be kept in mind that with organic materials the increases were measured from a base of zero materials added, whereas with fertilizer the increases were measured from a base application of 500 pounds per acre of a complete fertilizer and with irrigation the gains were measured from a base of the water supplied by natural rainfall.

EFFECTS ON YIELDS OF IRRIGATION, ORGANIC MATERIALS, AND FERTILIZER RATES USED IN COMBINATIONS. The effects on yields of the three practices, including interaction between the treatments, when used in combination were quite different from the effects of each used separately (Table 5). When each practice was used in combination with the other two practices, the average increases in yield of all crops in Series A for all years were as follows: 2,752 pounds per acre from irrigation over no irrigation,

4,987 pounds from organic material over no organic applications; and 3,116 pounds from 1,000 pounds over 500 pounds per acre of fertilizer. Making the same comparisons by seasons it may be noted (Table 5) that even more pronounced gains resulted from the combined treatments on fall and spring crops. On the other hand, the increases in yields of summer crops were less when used in combination with the other two practices than when used alone. Increases from irrigation, organic materials, and extra fertilizer were as follows: Fall crops, 5,480 pounds, 6,258 pounds, and 4,252 pounds; spring crops, 3,400 pounds, 6,360 pounds, and 4,268 pounds; and summer crops 223 pounds, 2,629 pounds, and 1,415 pounds.

Effects on yields from the three treatments have shown considerable interaction; that is, the effects of the two or three treatments used in combination were different from the sum of the effects of the two or three treatments used separately (Table 5). The nature of the interaction has varied among crops and especially among seasons. For example, the average increases in yields resulting from irrigation and organic materials used in combination were higher than from the sum of two practices used separately for all fall crops, for all spring crops, and for the average of all crops all seasons, but were lower for summer crops. Furthermore, where average increases in yield were larger from the combination of irrigation and organic materials than those from the two treatments used separately, the average increases were larger from the higher fertilizer rate than from the lower fertilizer rate.

Irrigation and higher fertilizer rates, likewise, gave higher average increases in yield from the two practices used in combination than from the two used separately for all fall crops, all spring crops, and all crops all seasons. Yield increases of summer crops from the combination averaged lower than the sum of increases from the two practices used separately.

Data for tendergreens (Appendix Table 4) illustrate the combined effects of irrigation and organic materials. Tendergreens for years of high response gave an increase of 12,006 pounds per acre from separate use of irrigation and organic materials (4,390 pounds + 7,616 pounds), whereas the increase from the two practices used in combination was 13,990 pounds (18,515 pounds − 4,525 pounds). The difference in the increases was 1,984 pounds per acre.

It should be noted that the same difference, 1,984 pounds, is obtained by subtracting the yield increase obtained when each

practice is used separately from the increase obtained when each is used in combination with the other practice (6,374 pounds – 4,390 pounds = 1,984 pounds; and 9,600 pounds – 7,616 pounds = 1,984 pounds).

Considering all years all crops, Series A, at the 500-pound fertilizer rate, beans, lettuce, corn, potatoes, tendergreen, and turnips gave larger increases from the combination of irrigation and organic materials than from the two practices used separately; at the 1,000-pound fertilizer rate, beans, cabbage, lettuce, potatoes, tendergreen, and turnips gave higher yields from the combination. Broccoli, cabbage, lima beans, and squash at the 500-pound fertilizer rate and sweet potatoes, broccoli, onions, and squash at the 1,000-pound rate yielded smaller increases from the combination than from the two practices used separately.

For all crops all years (Table 5), the increases in average yield per acre from the use of irrigation and organic materials in combination were 343 pounds per acre higher at the 500-pound fertilizer rate and 858 pounds higher at the 1,000-pound rate than the total of the increases from separate use of the two practices. The corresponding increases for fall crops in favor of the combinations were 904 pounds and 1,967 pounds, and for the spring crops 707 and 2,143 pounds per acre at the lower and higher fertilizer rates, respectively.

Increases in the average yield per acre of all 12 crops for all years from the use of irrigation and extra fertilizer in combination were 498 pounds higher without the organic treatment and 1,013 pounds higher with the organic treatment than the total of the increases from use of the two practices separately. The corresponding increases for the fall crops in favor of the combination were 1,208 pounds without and 2,271 pounds per acre with the organic treatment, and for the spring crops 132 without and 1,568 pounds per acre with the organic treatment.

Failure of the practices to give higher increase in yield when used in combination than when used separately occurred when one or more of the practices failed to give increases or when one or more of the practices gave excessive increases, as may be noted in the case of cabbage (Appendix Table 4, page 53).

Although the increases in yield resulting from two or more of the treatments used in combination were not higher for summer crops than from the use of the treatments separately, yields continued to increase from use of each successive treatment. For example, the average yield of all summer crops for all years was

4,289 pounds per acre at the lower fertilizer rate without irrigation and without organic materials added, whereas the average was 10,542 pounds per acre at the higher fertilizer rate with both irrigation and organic materials added. The increase, however, from irrigation after the extra fertilizer and organic materials had been added was very low.

CUMULATIVE EFFECTS OF INTENSIVE PRACTICES. Data in Appendix Tables 6 and 7 for certain treatments have been arranged in graphic form, Figures 3, 4, and 5, to show the cumulative effects of applying intensive practices. It may be seen from the graphs that yields continued to increase in most instances as successive treatments were added.

Irish potatoes illustrate the point under discussion. Yields of potatoes by treatment were as follows: no treatment, 28 bushels; 500 pounds per acre of fertilizer, 80 bushels; 1,000 pounds of fertilizer, 115 bushels; 1,000 pounds per acre of fertilizer plus the standard organic treatment, 162 bushels; and 1,000 pounds of fertilizer, standard organic treatment, plus irrigation, 229 bushels. The yields are for all years. Data for other crops in Series A show similar increases except in the case of winter onions, which gave no increase from irrigation.

In Series B, Figure 5, it will be noted that yields continued to increase as treatments became more and more intensive. In the case of some crops, however, the higher rates of fertilizers, 1,500 and 2,000 pounds, failed to increase yields to any extent.

EFFECTS OF DIFFERENT RATES OF IRRIGATION

Only a very limited amount of work has been done on irrigation rates. Yields from three treatments are given in Table 6. All treatments included 1,000 pounds per acre of fertilizer and the standard organic treatment for Series A. Irrigation in the three treatments consisted of 0, 1, and 2 inches per week. In each instance the yield was reduced by the higher rate of irrigation.

EFFECTS OF DIFFERENT KINDS OF ORGANIC MATERIALS WITH IRRIGATION

Yields from different organic materials used with irrigation are given in Tables 7 and 8. When used on crops under irrigation, the standard organic materials in Series A, Table 7, (2 tons of dry lespedeza sericea and 6 tons of green crotalaria) resulted in

TABLE 6. EFFECTS OF DIFFERENT AMOUNTS OF IRRIGATION ON YIELDS, SERIES A

Treatments			Yields per acre of different vegetables				
Fertilizer, 6-10-4 per acre	Organic materials[1]	Irrigation per week[2]	Beans, lima total summer, 1938-40	Beans, bush total spring, 1938-41	Onion total winter, 1938-41	Potatoes total spring, 1938-41	Turnip total fall, 1938-41
Lb.		*Inches*	*Bushels*	*Bushels*	*Pounds*	*Bushels*	*Pounds*
1,000	Standard	0	125	111	7,949	162	18,432
1,000	Standard	1	133	156	7,957	229	25,516
1,000	Standard	2	128	139	7,345	225	22,240
Increases from heavier over lighter irrigation			—5	—17	—612	—4	—3,276

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One and 2 inches of water per week were applied when rainfall during previous week had not supplied one inch.

TABLE 7. EFFECTS OF DIFFERENT ORGANIC MATERIALS WITH IRRIGATION, SERIES A

Treatments			Yields per acre of different crops									
Fertilizer, 6-10-4 per acre	Irrigation per week[1]	Organic materials[2]	Beans, bush, total spring 1938-41	Broccoli, heads, fall 1946-48	Cabbage, heads, spring 1942-45	Corn, sweet, mkt. ears, spring, summer 1946-48	Lettuce, total, fall 1946-47	Onion, total winter 1938-41	Potatoes, total, spring 1938-41	Sweet-potatoes, total, summer, fall 1943-45	Tender-green, total, fall 1943-45	Turnip, total, fall 1938-41
Lb.	*In.*		*Bu.*	*Lb.*	*Lb.*	*Doz.*	*Lb.*	*Lb.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*
1,000	1	0	91	2,408	9,091	515	7,280	3,822	130	373	13,494	18,615
1,000	1	Standard	156	4,161	20,281	809	17,050	7,957	229	415	21,180	25,516
1,000	1	Vetch	196	2,848	10,382	799	9,542	4,316	265	416	17,287	23,976
1,000	1	Cowpeas	116	3,358	15,387	666	10,637	5,116	189	372	17,507	22,255

[1] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[2] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer. Vetch and cowpeas were grown in plots and turned under.

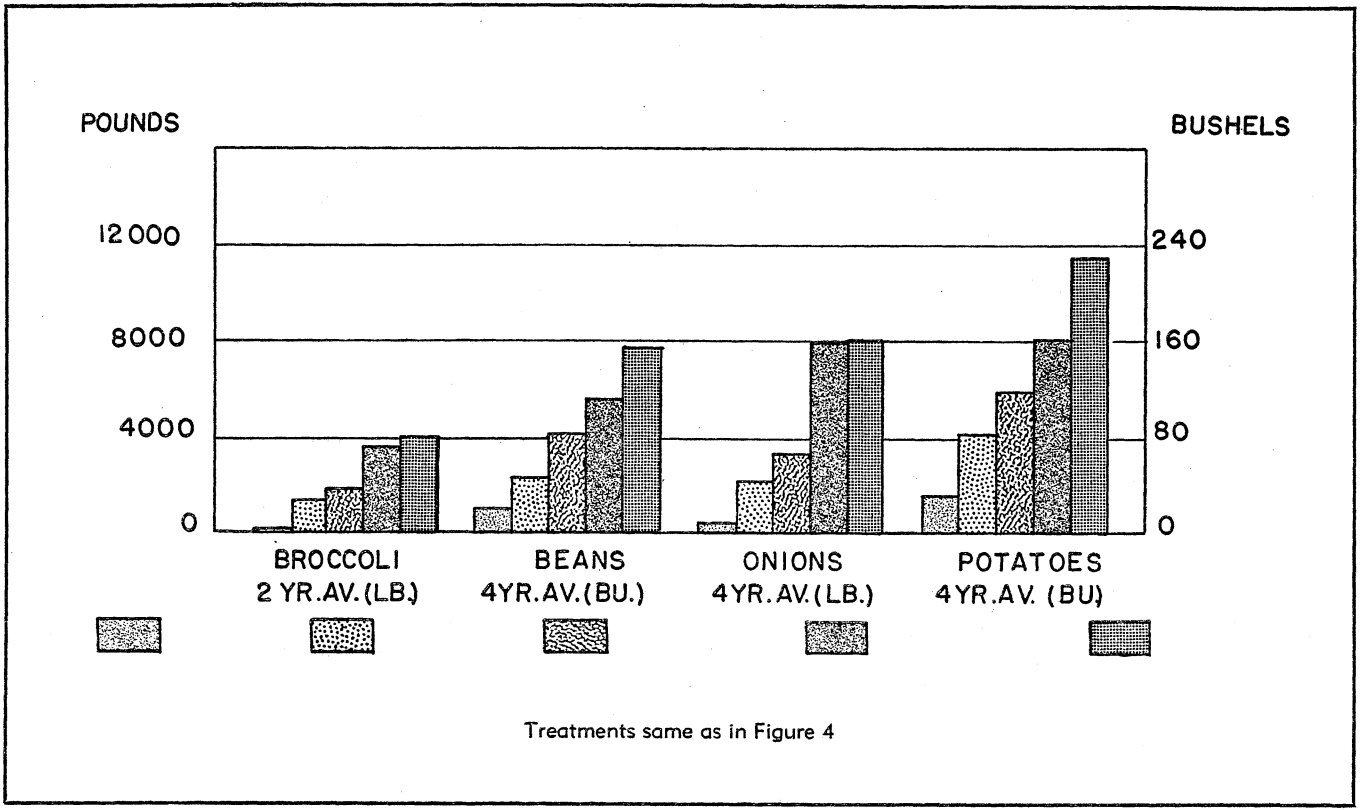


Figure 3. Cumulative effects of intensive practices on crop yields, Series A.

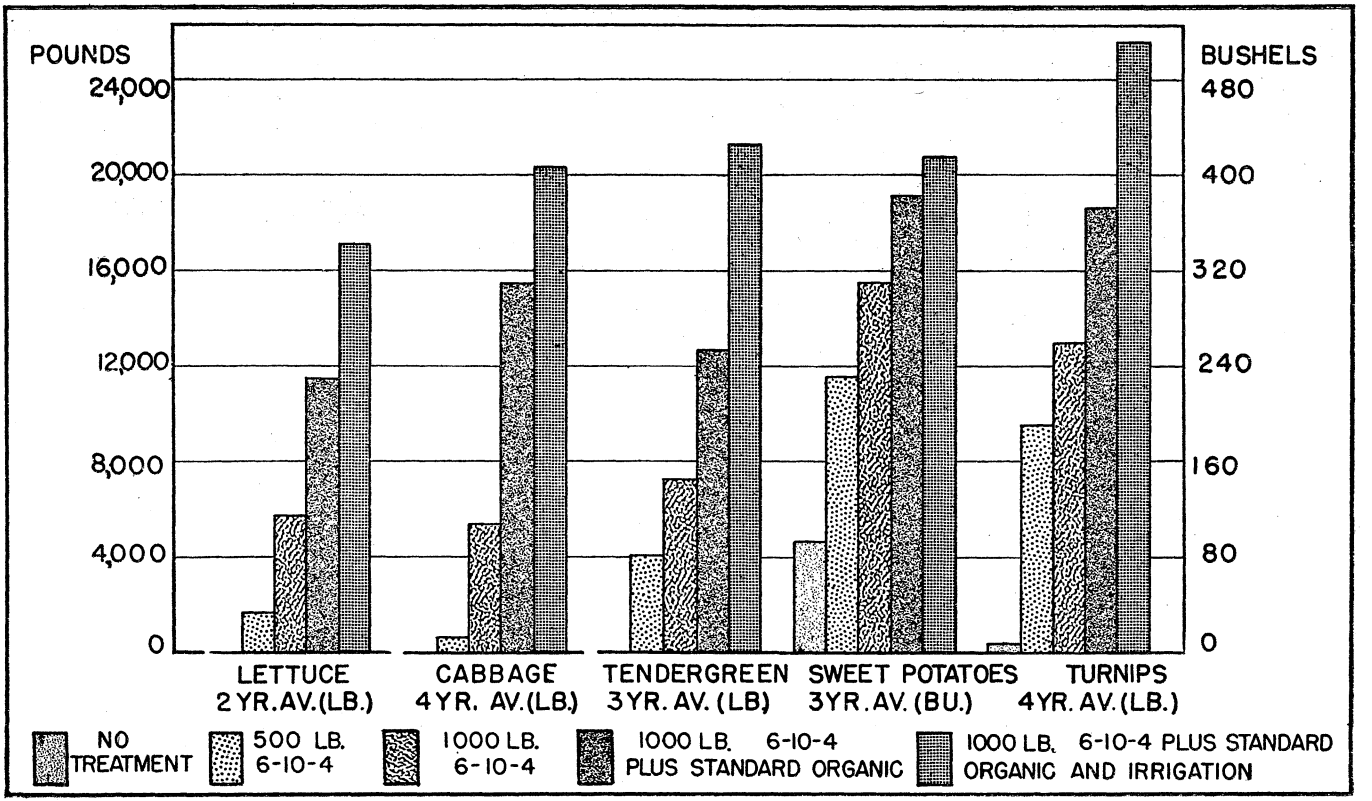


Figure 4. Cumulative effects of intensive practices on crop yields, Series A.

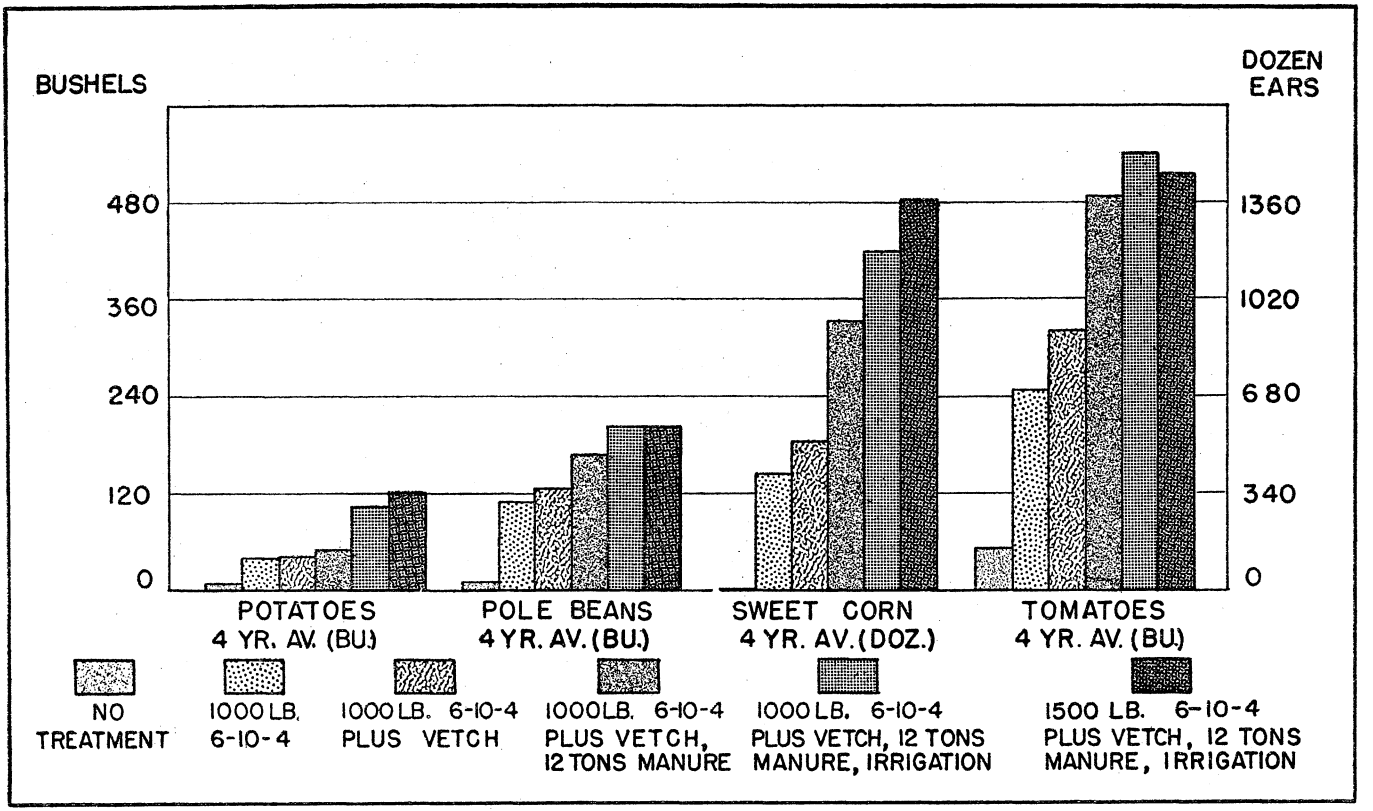


Figure 5. Cumulative effects of intensive practices on crop yields, Series B.

most of the crops producing as high or higher yields than where either vetch or cowpeas were grown and turned under. Vetch resulted in higher yields of spring potatoes and beans. On the other hand, there was little difference between the yields of sweetpotatoes and sweet corn from the standard organic materials and from vetch. In Series A, yields of all other crops resulting from the standard organic treatment were higher than those resulting from vetch. In all instances, yields from the standard organic materials were higher than from cowpeas, although the difference was not very great in the case of turnips.

In Series B, Table 8, higher yields were consistently obtained from 12 tons per acre of animal manure than from vetch or rye. Rye grown and turned under gave about the same increases as vetch. Yields from a combination of 6 tons of animal manure and vetch or of 6 tons of animal manure and rye were not quite as high as from 12 tons of manure. Twelve tons of animal manure and vetch produced higher yields of tomatoes and corn than 12 tons of animal manure alone. The yields of beans and potatoes were not increased by the addition of vetch to the animal manure.

Effects of Irrigation and Organic Materials on Grade of Products

Discussions and data presented to this point have been largely confined to gross effects of treatments. No data have been presented pertaining to effects of treatments on grade. Results in Tables 9, 10, 11, and 12 relate to effects of irrigation on the grade of a few selected crops. The crops chosen were those that permitted more specific measurements of differences, and included sweet corn, potatoes, sweetpotatoes, and tomatoes.

In Table 9 data are given for the number of dozen ears of marketable corn harvested, percentage of marketable ears, and average weight per dozen marketable ears from different organic treatments with and without irrigation. The data are for the year of highest response to irrigation, for the 2 years of high response, and for the 4-year average.

The increases from irrigation of corn receiving different organic treatments ranged from 413 to 986 dozen ears of marketable corn in 1948; the increases ranged from 274 to 646 dozen ears for the 1944 and 1948 average; and from 117 to 256 dozen ears for the 4-year period. The increases in percentages of marketable-ears resulting from irrigation with different organic treatments varied from 15 to 36 per cent in 1948, from 11 to 24 per cent in 1944 and

TABLE 8. EFFECTS OF DIFFERENT ORGANIC MATERIALS WITH IRRIGATION, SERIES B

Treatments				Yields per acre of different crops			
Fertilizer, 6-10-4 per acre	Irrigation per week[1]	Manures		Beans, pole, total, fall, 1944, 1946-48	Corn, sweet, marketable ears, summer, 1944, 1946-48	Potatoes, total, fall, 1940-43	Tomatoes, total, spring, 1940-43
		Animal	Green[2]				
Pounds	*Inches*	*Tons*		*Bushels*	*Dozens*	*Bushels*	*Bushels*
1,000	1	0	0	170	630	64	427
1,000	1	12	0	236	1,083	109	714
1,000	1	0	Vetch	154	653	76	550
1,000	1	0	Rye	199	817	76	470
1,000	1	6	Vetch	202	1,083	89	722
1,000	1	6	Rye	214	1,017	82	652
1,000	1	12	Vetch	202	1,190	103	785

[1] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[2] Green manure crops were grown and turned under.

TABLE 9. EFFECTS OF IRRIGATION ON NUMBER OF MARKETABLE EARS PRODUCED, PERCENTAGE OF MARKETABLE EARS, AND WEIGHT PER DOZEN EARS OF SWEET CORN WITH AND WITHOUT DIFFERENT ORGANIC MATERIALS, SERIES B

Treatments				Marketable ears								
	Manures			Number marketable ears			Percentage marketable ears			Weight ears per dozen		
Fertilizer, 6-10-4 per acre	Animal per acre	Green[1]		Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation[3]	Without irrigation	With irrigation	Increase from irrigation
		Legume	Non-legume									
Lb.	*Tons*			*Doz.*	*Doz.*	*Doz.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Pct.*
Year of highest response, 1948												
1,000	0	0	0	400	813	413	42	64	22	5.24	6.79	30
1,000	12	0	0	667	1,453	786	41	77	36	6.24	8.19	31
1,000	0	Vetch	0	480	1,147	667	39	66	27	6.36	7.87	24
1,000	0	0	Rye	733	1,240	507	59	74	15	6.39	7.43	16
1,000	12	Vetch	0	787	1,773	986	53	76	23	6.95	8.10	17
Average for years of high response, 1944, 1948												
1,000	0	0	0	353	660	307	38	57	16	6.51	7.38	13
1,000	12	0	0	773	1,280	507	52	76	24	7.98	9.00	13
1,000	0	Vetch	0	685	1,080	395	49	66	17	7.63	8.29	9
1,000	0	0	Rye	653	927	274	57	68	11	7.27	7.93	9
1,000	12	Vetch	0	940	1,586	646	63	78	15	7.76	8.93	15
Average for all years, 1944, 1946-48												
1,000	0	0	0	413	630	217	47	60	13	5.86	6.13	5
1,000	12	0	0	827	1,083	256	58	70	12	7.61	8.15	7
1,000	0	Vetch	0	525	653	128	48	58	10	7.38	8.00	8
1,000	0	0	Rye	700	817	117	58	67	9	7.17	7.31	2
1,000	12	Vetch	0	937	1,190	253	66	66	0	7.41	8.43	14

[1] Green manure crops were grown and turned under.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] The figures represent differences in percentage and not percentage difference.

1948, and from 0 to 13 per cent for the 4-year average. Percentage increases in the weight per dozen of marketable ears ranged from 16 to 31 per cent in 1948, from 9 to 15 per cent in 1944 and 1948, and from 2 to 14 per cent for the 4-year average.

Irrigation of corn, therefore, gave differences in the percentage of marketable ears and in the average weight per dozen ears which followed closely the differences in yields.

Total yields, yields of No. 1's, yields of marketable (No. 1's and No. 2's), percentage of No. 1's, and percentage of marketable fall Irish potatoes are given in Table 10. Without organic treatment and without irrigation, the percentage of No. 1 potatoes for the years of high response was only 9 per cent of the total yield; irrigation increased the No. 1's to 45 per cent. With animal manure added, irrigation increased the percentage of No. 1 potatoes from 32 to 46 per cent; with vetch added, the increase from irrigation was from 15 to 46 per cent; with rye added, from 11 to 57 per cent; and with both animal manure and vetch added, from 42 to 53 per cent. The increases in percentages of No. 1's from irrigation for the 4 years were smaller but consistent.

Total yield, yield of marketable, and percentage of marketable tomatoes are given in Table 11. There was not much difference between the percentages of tomatoes meeting the requirements of marketable grades produced with irrigation, and those grown without irrigation. This was true even in years of highest response.

Total yields, yields of marketable grades, yields of the jumbo grade, percentage of marketable grades, and percentage of jumbo grade of sweetpotatoes are given in Table 12. Substantial increases in yield of total and of marketable grades were obtained from irrigation with all treatments. Contrary to expectations, there was no increase in the yield of jumbo grade from irrigation. Small but consistent increases in the percentage of marketable potatoes were obtained from irrigation in years of high response and for the average of all years. The percentages of the jumbo grade were somewhat less for all treatments receiving irrigation than for those not receiving irrigation.

Results with Individual Crops

Data on total yield and yield of the used portions, where different from the total, are given in Appendix Tables 6 and 7 for each of the 16 crops in both series for all treatments. The data are the averages of all years and for selected years of high

TABLE 10. EFFECTS OF IRRIGATION ON YIELDS AND GRADES OF FALL-GROWN POTATOES WITH AND WITHOUT DIFFERENT ORGANIC MATERIALS, SERIES B

Treatments			Average yields per acre						Yields in percentage			
Fertilizer, 6-10-4 per acre	Manures		Total		No. 1's		Marketable		No. 1's		Marketable	
	Animal per acre	Green[1]	Without irrigation	With irrigation[2]	Without irrigation	With irrigation	Without irrigation	With irrigation	Without irrigation	With irrigation	Without irrigation	With irrigation
Lb.	*Tons*		*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Average for years of high response, 1940-41												
1,000	0	0	22	56	2	25	14	44	9	45	64	79
1,000	12	0	19	93	6	43	12	71	32	46	63	76
1,000	0	Vetch	20	65	3	30	13	49	15	46	65	75
1,000	0	Rye	18	58	2	33	9	50	11	57	50	85
1,000	12	Vetch	24	97	10	51	15	83	42	53	63	86
Average for all years, 1940-43												
1,000	0	0	37	64	10	28	27	50	27	44	73	78
1,000	12	0	50	109	22	54	40	87	43	50	80	80
1,000	0	Vetch	41	76	14	35	30	59	34	46	73	78
1,000	0	Rye	40	76	12	38	28	62	30	50	70	82
1,000	12	Vetch	49	103	23	56	39	87	47	54	80	84

[1] Green manure crops were grown and turned under.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

TABLE 11. EFFECTS OF IRRIGATION ON YIELDS AND GRADES OF TOMATOES WITH AND WITHOUT DIFFERENT ORGANIC MATERIALS, SERIES B

Treatments			Average yields per acre				Percentage marketable	
Fertilizer 6-10-4 per acre	Manures		Total yields		Marketable yields		Without irrigation	With irrigation
	Animal	Green[1]	Without irrigation[2]	With irrigation	Without irrigation	With irrigation		
Lb.	*Tons*		*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Pct.*
			Average for years of high response, 1942-43					
1,000	0	0	218	301	134	188	61	62
1,000	12	0	466	582	333	405	71	70
1,000	0	Vetch	252	346	168	203	67	59
1,000	0	Rye	315	371	195	247	62	67
1,000	12	Vetch	476	543	327	361	69	66
			Average for all years, 1940-43					
1,000	0	0	369	427	246	284	67	67
1,000	12	0	709	714	507	493	72	69
1,000	0	Vetch	467	550	322	354	69	64
1,000	0	Rye	461	470	307	320	67	68
1,000	12	Vetch	697	785	485	538	70	69

[1] Green manure crops were grown and turned under.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

TABLE 12. EFFECTS OF IRRIGATION ON YIELDS AND GRADES OF SWEETPOTATOES FROM DIFFERENT RATES OF FERTILIZER WITH AND WITHOUT ORGANIC MATERIALS, SERIES A

Treatments		Average yields per acre						Percentage			
		Total		Marketable		Jumbos		Marketable		Jumbos	
Fertilizer 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[2]	Without irrigation	With irrigation	Without irrigation	With irrigation	Without irrigation	With irrigation	Without irrigation	With irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
		Average for years of high response, 1944-45									
500	0	212	244	163	196	0	0	77	80	0	0
500	Standard	321	399	260	347	15	0	81	87	5	0
1,000	0	282	373	230	317	0	0	82	85	0	0
1,000	Standard	387	424	331	384	7	6	86	91	2	1
		Average for all years, 1943-45									
500	0	232	277	189	229	0	5	81	83	0	2
500	Standard	352	399	279	348	38	9	79	87	11	2
1,000	0	309	373	253	320	12	7	82	86	4	2
1,000	Standard	383	415	317	364	30	23	83	88	8	6

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

response. Rainfall data by semi-monthly periods for each year of the investigation are given in Appendix Table 1. Dates of planting and number of irrigations applied to each crop are given in Appendix Table 8. Data in these tables will permit detailed study of response to the treatments of any crop and the relation of response to rainfall.

Economic Studies

Yield differences from treatments have been the only basis on which values have been measured in the data presented to this point. In the final analysis, the grower is concerned with dollar return for dollar outlay. Experiments were, therefore, conducted as part of this study to measure the cost of production, labor requirements, and returns obtained from crops grown under irrigation. These studies have been briefly outlined under "Methods and Materials." The data from this phase of study are used as a basis for computing the value of increased yields obtained from irrigation in the field-bin studies.

Costs, Labor Requirements, and Returns from Crops Grown Under Irrigation. Results obtained on costs, labor requirements, and returns from crops grown under irrigation are based on experiments conducted in 1946 and 1947 on a field basis. Pole beans, sweet corn, lima beans, and fall Irish potatoes were grown both years. A number of other crops were grown one year. Several successions of pole beans and corn were grown. Each succession was treated as a separate set of data.

Preparation of land was done with mules; hauling of manure was by truck; irrigation was done with a portable irrigation system; and planting, dusting, and harvesting were done by hand.

The capacity of the pump was 180 gallons per minute; the main and lateral pipes were 3 inches in size; and the 10 sprinklers each had a capacity of 18 gallons per minute. Theoretically, 0.53 acre was irrigated at one setting of the system. Three men moved the sprinklers to a new setting in 20 minutes. Theoretically, 2.5 hours of continuous pumping was required to deliver one acre-inch. The studies show that considering loss of time for servicing pump and engine, placing the engine and pump, priming the pump, laying the pipes, and moving the laterals and sprinklers, 3.65 hours were required to deliver one acre-inch. Three acre-inches were, therefore, delivered in approximately 11 hours. Labor

was used for other work when not engaged in moving the pipes and sprinklers from one position to another.

It should be emphasized that this phase of the work does not show the effects of irrigation; it only shows data on costs and labor requirements of producing crops under irrigation. Records from field bins necessarily were used to determine the amount of increases from irrigation and the estimated value of increases.

Data on labor and equipment requirements and costs of applying one acre-inch of water for three crops of pole beans, five crops of sweet corn, and one crop each of lima beans and fall potatoes are given in Table 13. On a basis of 10 crops, the average cost per acre-inch of applying irrigation at prevailing farm wages and material costs at the time of the experiment was $5.56. This does not include a charge for upkeep and amortization of the pond.

Data on costs, labor requirements, yields, and returns from production of three crops of beans, five crops of sweet corn, and one crop each of lima beans and potatoes are given in Table 14. Data on pole beans may be used to illustrate use of the table. The average yield per acre of beans was 412 bushels, the cost $825.54, and the gross sale value $1,235. The value above cost of beans was $409.46 per acre. An average of 3⅔ inches of irrigation was applied at a cost of $21.43. Data for the other crops are given in the table.

It will be noted that irrigation costs for beans were only 2.60 per cent of the total cost of producing and harvesting the crop, for corn 10.68 per cent, for lima beans 4.36 per cent, and for

TABLE 13. LABOR REQUIREMENTS, EQUIPMENT TIME, FUEL CONSUMPTION, AND TOTAL COST PER ACRE-INCH OF IRRIGATION

Items	Beans, pole (3-crop av.)	Corn, sweet (5-crop av.)	Beans, lima (1-crop)	Potatoes (1-crop)	Weighted average of 10 crops	Cost	
						Per unit	Total
						Dol.	*Dol.*
Labor, hours	5.45	3.60	7.49	7.77	4.96	0.35	1.74
Equipment, hours	3.80	3.50	3.80	3.80	3.65	0.50	1.83
Gasoline, gallons	7.60	7.08	8.00	7.67	7.39	0.26	1.92
Oil, quarts	0.24	0.26	0.20	0.33	0.26	0.25	0.07
						TOTAL	5.56[1]

[1] This amount does not include charge for upkeep and for amortization of pond. The amount of this charge would generally range from 10 to 25 cents per acre-inch, assuming one-half of cost is charged to fishing and recreation and one-half to irrigation.

TABLE 14. COSTS, LABOR REQUIREMENTS, YIELDS, RETURNS, IRRIGATION GIVEN AND IRRIGATION COSTS PER ACRE IN PRODUCING VEGETABLE CROPS UNDER IRRIGATION

Items	Data by crops per acre			
	Beans, pole 1947 (3-crop av.)	Corn, sweet 1946-1947 (5-crop av.)	Beans, lima 1947 (1 crop)	Potatoes, Fall, 1947 (1 crop)
Labor, man hours				
Total	1,675	131	576	154
Harvesting	1,032	50	499	44
Irrigating	20	9	15	23
Yields harvested, bushels	412	857[1]	153	204
Total costs, dollars	825.54	119.78	304.95	239.28
Value of products, dollars	1,235.00	296.53	459.00	428.40
Value above cost, dollars	409.46	176.75	154.05	189.12
Irrigations, average number	3.67	2.60	2.00	3.00
Cost of irrigation,[2] average, dollars	21.43	12.79	13.30	20.07
Cost of irrigation in relation to total, per cent	2.60	10.68	4.36	8.39

[1] Sweet corn yields were in dozen ears per acre.
[2] Average cost per acre-inch of irrigation was $5.56 without charge for pond amortization.

fall potatoes 8.39 per cent. The total cost of applying 29 acre-inches of water to the 10 crops was $161.24. On the basis of an average of 4.89 acre-inches per crop (Appendix Table 8) and a cost of $5.56 per acre-inch (Table 13), the average cost per crop of irrigation was $27.19 per acre.

RETURNS FROM USE OF IRRIGATION AND ORGANIC MATERIALS. In Appendix Tables 9 and 10 are given data on the gross value and value above cost of the practice or practices for increases obtained from irrigation with and without organic materials, from organic materials with and without irrigation, and from both practices for each of the crops in Series A and B. Data in Appendix Table 9 are for the year or years of high response, and results in Appendix Table 10 are for all years. The fertilizer rate was 1,000 pounds per acre. The standard organic treatment in Series A consisted of 2 tons of lespedeza sericea applied in late winter and 6 tons of crotalaria applied in late summer, while 12 tons of animal manure was the standard organic treatment in Series B.

Cost data obtained on the field plots were used in calculating the cost of the practices. The data on increases in yields are derived directly from the bin experiments and are, therefore, basic under the conditions of the experiment. The data on gross and net values of increases are based on assumed values[2] and would, therefore, vary with prices assumed.

In Table 15 is given a summary of the data in Appendix Tables 9 and 10. The table gives average values for crops by seasons for all years, average values for all crops all years, and average values for all crops for the years of high response to irrigation.

Considering all crops all years, the value above cost of the practices was $34.86 per acre from irrigation without organic materials, $50.79 from irrigation with organic materials, $135.19 from organic materials without irrigation, $151.12 from organic materials with irrigation, and $185.98 from use of both treatments.

The returns above cost of irrigation for the increased yields from use of irrigation for fall crops were $67.22 without and $125.55 with organic materials, and for the spring crops $6.25 without and $75.81 with organic materials. Summer crops returned $36.28 above costs for the increased yields from use of irrigation without organic materials and only $16.78 with organic materials added.

The average values above cost of the treatment for the increased yields resulting from irrigation with organic materials added were $125.55 for fall crops, $75.81 for spring crops, and $16.78 for summer crops, and $50.79 for all crops. The returns above cost of irrigation for the increase for all crops for years of high response to irrigation was $120.64.

It has been pointed out earlier that increases in yield under certain conditions and at certain seasons were larger from use of the practices in combination than from use of the practices separately. It is pointed out that yield increases from use of practices in combination over those from practices used separately are made with no extra cost, since the cost of each practice is charged separately. The values of these yield increases are therefore net values. These increases in value amounted to $58.33 for all fall

[2] In arriving at the value of increased yields, the following farm prices for products were used: beans and lima beans, $2.40 per bushel; tomatoes, $2.00 per bushel; potatoes, $2.10 per bushel for No. 1 grade and $1.05 for No. 2 grade; sweetpotatoes, $2.50 per bushel for No. 1 grade and $1.25 for No. 2 grade; sweet corn, 30 cents per dozen ears; broccoli, 10 cents per pound; cabbage, 2 cents; lettuce, 4 cents; onions, 6 cents; squash, 3 cents; tendergreen, 2 cents; and turnips, 2 cents.

crops all years, $69.56 for all spring crops all years, and $15.92 for all crops all years. Returns were $19.58 less from the combination than from the two practices used separately for all summer crops all years.

Irrigation without organic materials failed to give increases in yield sufficient to justify the cost of application (average of all years) on lima beans, snap beans, sweet corn (Series A), onion, spring potatoes, and squash (Appendix Table 10). Lima beans, sweet corn (Series A), onions, squash, and tomatoes failed to

TABLE 15. GROSS VALUES AND VALUES ABOVE COSTS PER ACRE OF PRACTICES FROM YIELD INCREASES RESULTING FROM DIFFERENT TREATMENTS AT DIFFERENT SEASONS

Bases of values	Values of increases for different seasons and different treatments[1]				
	From irrigation[2]		From organic materials[3]		From both irrigation and organic materials
	Without organic materials	With organic materials	Without irrigation	With irrigation	
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Fall crops,[4] all years					
Gross returns	91.49	149.82	156.13	214.46	305.95
Returns above cost	67.22	125.55	131.13	189.46	256.68
Spring crops,[5] all years					
Gross returns	33.65	103.21	112.34	181.90	215.55
Returns above cost	6.25	75.81	87.34	156.90	163.15
Summer crops,[6] all years					
Gross returns	63.63	44.13	165.29	145.79	209.42
Returns above cost	36.28	16.78	140.30	120.80	157.08
All crops,[7] all years					
Gross returns	62.98	78.90	160.20	176.12	239.10
Returns above cost	34.86	50.79	135.19	151.12	185.98
All crops,[7] years of high response					
Gross returns	126.42	148.20	170.81	192.59	319.01
Returns above cost	98.86	120.64	145.81	167.59	266.45

[1] All crops received 1,000 pounds of 6-10-4 per acre.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] In series A, 2 tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer; in series B, 12 tons per acre of animal manure was applied in late winter.
[4] Fall crops consisted of broccoli, lettuce, tendergreen, and turnip in series A.
[5] Spring crops consisted of beans, cabbage, and potatoes in series A.
[6] Summer crops consisted of corn, lima beans, squash, and sweetpotato in series A and pole beans, corn, potatoes, and tomatoes in series B.
[7] All crops included those grown in series A and series B.

give increases in yield from irrigation with organic materials sufficient to justify the cost of irrigation. Only lima beans failed to give returns for all years above costs from use of both practices.

These comments may be made on the crops and the conditions under which irrigation failed to justify the cost of application. The lima bean responds rather indifferently to good agricultural treatments. It is drought resistant and produces well without much fertilizer and water. The onion was grown during the winter when soil moisture was adequate and moisture requirements were low. Rainfall during the growing period of sweet corn in Series A was favorable 3 of the 4 years of the experiment. Results from irrigation of tomatoes and squash were complicated by difficulties with fruit setting and decay, conditions which seemed to be more aggravated when organic materials were used with irrigation.

Crops showing small increases and low returns would be eliminated in practice, while crops showing high returns would be selected.

DISCUSSION

In few large areas of the world is rainfall more favorable to crop production than in the southeastern United States. Of this area Israelsen *(8)* says, "In some parts of the Eastern United States the natural rainfall usually supplies enough water to meet all the need of growing crops." The study reported here was conducted in this area where rainfall is so favorable.

It is certain that irrigation does not increase yields of all crops every year or every season. The data do show that increases in yield some years are very marked and that the average yields of most crops are increased by irrigation over a period of years. The data show rather conclusively that irrigation, high rates of fertilizer, and organic materials over a period of years accounted for increased yields when used separately. They also show that the effects of the three treatments are cumulative, and that, under certain conditions and during certain seasons, the increases in yield are generally greater when each is used in combination with the other treatments than when used separately.

Relation of Climate to Response from Irrigation

That irrigation should not give increased yields each year or season is to be expected. Weather data show that there are great fluctuations in the amount and distribution of rainfall from year to year for the State, from area to area within the State, and from season to season in each area. Likewise, cloudiness, humidity, and wind are variable.

The data in Table 4 and Appendix Tables 2 and 3 indicate that there is not a very close relationship between total rainfall during the growing season of a crop and its response to irrigation; the relationship between response to irrigation and the distribution of rainfall, especially the occurrence and length of drought periods, is more pronounced.

It would seem that a closer relationship should exist between response to irrigation in a given season and rainfall during that season. When, however, the effects of other factors are considered, it is obvious that the relationship would not be very close. Factors other than available moisture in the soil affect the amount of water used by plants. Miller *(14)* states that differences as high as 600 per cent may occur in water losses on successive days due to weather conditions. A short period of hot, dry, windy weather may cause damage to plants and greatly reduce the photosynthetic efficiency of plants. Thoday *(24)* found, for example, that the photosynthetic rate of rigid leaves was 10 times that of plants drooping or wilted. Assume identical rainfall in two successive years for a given crop in which one inch of rain fell each week on the same day and that the full amount was absorbed by the soil. Assume, however, that there were in one year a number of periods of low humidity, high temperature, and much wind but few or no such periods in the other year. With an assumed water loss and use during critical periods twice as great one year as the other, it would be obvious that the identical amounts of rainfall might be much below the requirements for maximum production one year but adequate the other year. Irrigation, therefore, would most likely show benefits one year but little or no benefits the other year, even though rainfall were identical and normally adequate.

Relation of Soil Characteristics to Irrigation Needs

With other factors favorable, satisfactory growth depends to a considerable extent upon adequate soil moisture. Many factors

enter into the complex that determine whether a soil has or will have adequate quantities of available moisture to enable plants to make maximum yields.

The water reservoir for growing crops is the capillary moisture of the soil. Soils of a given texture and organic matter content can retain only a certain amount of water. Soils vary greatly in moisture-holding capacity and in availability of moisture they hold. Soils of light texture will normally hold, in available form, water equivalent to about 1⅓ inches of rainfall, or about 36,000 gallons per acre in the top 2 feet of soil, those of medium texture about 2⅔ inches, and those of fine texture about 4 inches.

While young crops draw on the soil for only a limited amount of water, crops at the time of maximum growth draw on the soil for great quantities. For heavy users, this will often amount to as much as 1½ inches or about 40,000 gallons of water per acre per week. The moisture reserves of the soil thus may be exhausted within a period of 2 or 3 weeks. The water supply therefore, must be replenished if crops are not to suffer. Rapidly growing crops on light soils usually begin to suffer for water if rain does not fall within 2 or 3 weeks. A study of drought frequencies in Table 2 will reveal the odds that drought periods of 2, 3, or 4 weeks will occur at different seasons of the year at different locations in Alabama. It is during these periods that irrigation serves its purpose of providing water.

Since soil moisture held as capillary moisture is lost by evaporation and by transpiration of plants, it may be assumed that three-fourths to one inch per week of water should be available or provided during the early period of growth and from 1 to 1½ inches per week during the period of rapid growth if rain has not supplied those amounts. The data show that nothing is gained by irrigation if rainfall supplied such amounts. On the other hand the data show that, when rainfall fails to provide the required amounts, irrigation increases yields and gives higher gross and net returns.

Effects from Use of Practices in Combinations

It has been shown that the effects of successively adding the treatments are cumulative. It has also been shown that, under certain conditions and with certain crops, the effects of one practice are increased when used in combination with other practices.

Although the increased yields obtained from the use of two

practices in combination above those obtained from the two practices used separately is correctly a mutual effect, in practical application the amount of this mutual effect may be attributed to the use of one practice alone if the other is normally used. For example, the value above cost from the use of irrigation was only $6.25 per acre for the average of all spring crops for all years without organic materials; the value above cost was $75.81 from irrigation with organic materials. If a grower generally adds organic materials but not irrigation, irrigation might, therefore, be credited with an increase of $75.81; or if irrigation was planned without organic materials, the addition of organic materials might be given credit for the amount of the mutual effect.

While results obtained under the condition of this experiment show, in general, that use of two or more practices in combination gave higher yield increases than use of the practices separately for fall and spring crops, the reverse was generally true with summer crops. More research is needed to determine: (1) whether the particular summer crops used responded differently to treatments than did fall and spring crops; (2) whether there were basic differences in effects of the treatments on the soil during the summer as compared to those during the spring and fall; and (3) whether drought periods during the summer were sufficiently different from those in the spring and fall to account for response differences.

SUMMARY

The results of irrigation studies with vegetable crops extending over 11 years are reported in this bulletin.

The investigation consisted of two phases. One was to measure the effects of irrigation with and without use of other good agricultural practices. The other was to obtain data on costs, labor requirements, and returns from production of crops under irrigation.

The basic treatments consisted of applications of irrigation, organic materials, and different fertilizer rates.

The following results were obtained:

Irrigation gave marked increases some years and little or no increase other years, yields some years being less with than without irrigation.

Response to irrigation was more closely related to distribution of rainfall than to the total amount of rainfall during the life of a crop.

The average increases in yield of all crops for all years resulting from the use of each practice without either of the other two practices was 1,396 pounds per acre from irrigation, 4,655 pounds from organic materials, and 2,629 pounds per acre from additional fertilizer.

When each practice was used in combination with the other two practices, the average increases of all crops all years were 2,752 pounds per acre from irrigation, 4,987 pounds from organic materials, and 3,127 pounds from the higher fertilizer rate.

The average increases in yield were higher from use of irrigation and organic materials used in combination than from use of the two practices separately for fall crops, for spring crops and for all crops all seasons, but not for summer crops. Where the increases were higher, the amounts of the increases resulting from the use of irrigation and organic materials in combination over those resulting from the use of the two practices separately were higher at the higher fertilizer rate than at the lower fertilizer rate.

The average increases in yield of fall crops, spring crops, and all crops all years were higher from irrigation and extra fertilizer used in combination than from separate use of the two practices.

Where average increases were higher, the resulting increases from use of irrigation and higher fertilizer rates in combination over those from the use of the two separately were higher with than without organic materials.

Effects of treatments were cumulative. Yields, in general, continued to increase as fertilizer rates were increased, organic materials added, and irrigation applied. Limits were approached when 1,000 pounds per acre of a 6-10-4 fertilizer, 12 tons of stable manure, a crop of vetch, and 1 inch of water per week were added. Increasing the fertilizer from 1,000 to 1,500 pounds per acre after all other treatments were given usually resulted in little or no further increase in yield.

Irrigation improved the grade and quality and gave higher yields of marketable products. Effects were generally more pronounced in seasons of high response and when organic materials were used with irrigation.

The yield of marketable sweet corn (Series B), for the 2 years of high response was increased 307 dozen ears per acre, the percentage of marketable ears was increased from 38 to 57 per cent, and the weight of marketable ears was increased from 6.51 to 7.38 pounds per dozen from irrigation without organic materials. Irrigation when used with 12 tons of animal manure for the same years increased the yield 507 dozen ears, the percentage of marketable ears from 52 to 76, and the weight from 7.98 to 9.00 pounds per dozen ears.

Effects of irrigation on the percentage of marketable crop were more pronounced on fall potatoes but less pronounced on sweetpotatoes and tomatoes than on corn.

An average of approximately 5 inches (4.89) of irrigation per crop was applied in this study. The number ranged from 3 inches for short-season crops to 9 inches for long-season crops.

The cost of applying irrigation under the conditions of the larger field experiment was $5.56 per acre-inch, not including an amortization charge against cost of the pond.

For the years of high response to irrigation, the average value of the increased yields above cost of the practices for all crops was $98.86 from irrigation without organic materials, $120.64 from irrigation with organic materials, $145.81 from organic materials without irrigation, $167.59 from organic materials with irrigation, and $266.45 from both irrigation and organic materials.

For all crops all years, the average value of the increased yield above cost of the practices was $34.86 from irrigation without organic materials, $50.79 from irrigation with organic materials, $135.19 from organic materials without irrigation, $151.12 from organic materials with irrigation, and $185.98 from both irrigation and organic materials.

The average values of the increased yields from irrigation above cost of the practice for all years for fall crops were $67.22 without and $125.55 with organic materials; for spring crops, $6.25 without and $75.81 with organic materials; and for summer crops, $36.28 without and $16.78 with organic materials.

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APPENDIX

APPENDIX TABLE 1. RAINFALL DATA BY SEMI-MONTHLY PERIODS FOR YEARS OF EXPERIMENT, AUBURN, ALABAMA, 1938-48[1]

Year	March		April		May		June		July		August		September		October		November	
	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-30
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1938	0.13	4.69	9.76	0.97	2.73	1.40	0.73	2.49	2.05	5.71	2.41	0.87	1.93	0.09	0.17	0.14	0.22	1.82
1939	1.43	5.64	0.69	3.61	0.74	2.12	1.77	1.96	0.35	3.73	2.55	6.78	0.60	3.40	0.01	0.09	0.33	0.10
1940	5.07	2.83	1.63	0.90	0.07	1.30	5.39	2.93	6.68	0.73	0.76	2.57	0.17	0.73	0.23	0.94	2.45	0.35
1941	2.86	1.16	0.63	2.41	0.83	0.01	1.77	2.69	2.43	2.54	3.84	1.37	1.41	1.51	1.02	1.60	1.28	0.96
1942	3.94	4.90	2.22	0.00	1.67	2.33	4.87	1.34	1.65	1.75	3.20	2.85	0.72	3.08	1.38	0.92	0.72	1.12
1943	4.70	11.10	0.76	1.82	3.24	1.22	0.59	1.14	2.91	2.07	3.80	0.22	2.04	1.02	0.69	0.03	3.77	0.67
1944	0.69	11.75	2.12	9.46	1.10	0.51	1.03	0.80	1.76	4.21	6.15	4.88	4.10	2.12	0.36	0.00	0.04	3.33
1945	2.54	1.52	1.32	9.13	4.30	1.26	1.14	6.52	2.37	6.19	1.54	0.27	1.86	0.65	1.05	2.43	0.59	2.73
1946	2.51	4.25	0.51	1.86	4.01	4.10	3.79	3.20	2.45	2.47	2.14	0.40	2.01	2.08	0.77	1.04	1.04	2.81
1947	3.44	2.64	4.30	1.56	1.13	3.74	0.38	2.45	0.00	2.40	2.30	1.23	2.95	0.03	0.32	0.85	6.97	2.52
1948	8.11	3.78	1.63	0.00	0.97	1.23	2.18	3.63	9.07	1.55	5.50	0.18	2.48	2.77	1.19	0.17	2.86	14.91

[1] Data from local weather station.

APPENDIX TABLE 2. INCREASES IN YIELDS FROM IRRIGATION AS INFLUENCED BY AMOUNT AND DISTRIBUTION OF RAINFALL BY YEARS WITHOUT ORGANIC MATERIALS

Crops and seasons[1]		Units	Increases in yields by years and amount and distribution of rainfall by periods				
Series A							
Beans, bush, total spring	Year		1938	1939	1940	1941	4-yr. av.
	Increase	Bushels	—34	—24	42	53	9
		Per cent	—17	—23	350	589	11
	Rainfall	Amount[2]	AACB	ADAA	ADDA	CDDB	
		Distribution[3]	abcb	accb	bcdb	cddb	
Broccoli, heads, fall	Year		1946	1947	1948		3-yr. av.
	Increase	Pounds	—176	1,824	340		663
		Per cent	—11	103	18		38
	Rainfall	Amount	BCCA	CAAA	CBCA		
		Distribution	bcca	ccbb	cccb		
Cabbage, heads, spring	Year		1942	1943	1944	1945	4-yr. av.
	Increase	Pounds	5,868	—864	6,099	—4,890	1,553
		Per cent	34	—8	157	—26	12
	Rainfall	Amount	ACDA	ABBC	AAAD	AACA	
		Distribution	ccdb	cccc	babc	aacb	
Lettuce, total fall	Year		1946	1947			2-yr. av.
	Increase	Pounds	—3,194	6,388			1,597
		Per cent	—38	217			28
	Rainfall	Amount	ACCB	BDAA			
		Distribution	bccb	bdba			
Potatoes, total spring	Year		1938	1939	1940	1941	4-yr. av.
	Increase	Bushels	—6	—11	13	66	15
		Per cent	—3	—10	18	65	13
	Rainfall	Amount	CACB	CAAC	ABDA	BDBD	
		Distribution	cacb	cbcc	abda	bdcd	
Sweetpotatoes, total summer and fall	Year		1943	1944	1945		3-yr. av.
	Increase	Bushels	10	98	85		64
		Per cent	3	34	31		21
	Rainfall	Amount	BCBC	DCAA	BAAC		
		Distribution	ccbb	ccaa	babc		

(*Continued*)

[1] All crops received 1,000 pounds of 6-10-4 fertilizer per acre.

[2] Rainfall by periods: A = rainfall above 1.2 inches per week; B = rainfall of .8 to 1.2 inches; C = rainfall of .4 to .8 inch; D = rainfall of 0 to .4 inch. Order of symbols corresponds to four equal periods beginning one week before planting and extending to one week before final harvest.

[3] Distribution and amount of rainfall within each period: a = excellent; b = good; c = fair; and d = poor. Symbols from left to right correspond to periods from first to fourth period.

APPENDIX TABLE 2. (*Continued*) INCREASES IN YIELDS FROM IRRIGATION AS INFLUENCED BY THE AMOUNT AND DISTRIBUTION OF RAINFALL BY YEARS WITHOUT ORGANIC MATERIALS

Crops and seasons[1]		Units	Increases in yields by years and amount and distribution of rainfall by periods				
Series A							
Tendergreen, total fall	Year		1943	1944	1945		3-yr. av.
	Increase	Pounds	5,561	7,412	5,433		6,136
		Per cent	63	215	55		83
	Rainfall	Amount[2]	DDAD	ACDD	BCCD		
		Distribution[3]	ddcd	ccdd	bccd		
Turnip, total fall	Year		1938	1939	1940	1941	4-yr. av.
	Increase	Pounds	3,349	7,080	11,505	679	5,653
		Per cent	49	50	395	2	44
	Rainfall	Amount	DDDB	BDDD	DDDB	CCCC	
		Distribution	dddc	cddd	cddb	cccc	
Series B							
Beans, pole, total summer and fall	Year		1944	1946	1947	1948	4-yr. av.
	Increase	Bushels	12	67	44	127	62
		Per cent	300	93	24	76	57
	Rainfall	Amount	AAAC	BCDA	BBDD	ACBC	
		Distribution	abbc	bcdb	ccdd	bccd	
Corn, sweet, marketable, spring and summer	Year		1944	1946	1947	1948	4-yr. av.
	Increase	Dozen ears	200	27	227	413	217
		Per cent	65	18	28	103	53
	Rainfall	Amount	ADCC	BCAA	BCCB	DDCA	
		Distribution	bddc	bcaa	bccc	cddb	
Potatoes, total summer and fall	Year		1940	1941	1942	1943	4-yr. av.
	Increase	Bushels	48	21	25	15	27
		Per cent	171	131	32	56	72
	Rainfall	Amount	BDDB	ACCD	ADAC	BCDD	
		Distribution	cddb	bccc	bdbc	bbcc	
Tomatoes, total, spring and summer	Year		1940	1941	1942	1943	4-yr. av.
	Increase	Bushels	44	23	6	160	58
		Per cent	9	4	2	114	15
	Rainfall	Amount	ADAA	BDCA	DAAC	ACBA	
		Distribution	adab	cdcb	dbbd	bcba	

[1] All crops received 1,000 pounds of 6-10-4 fertilizer per acre.

[2] Rainfall by periods: A = rainfall above 1.2 inches per week; B = rainfall of .8 to 1.2 inches; C = rainfall of .4 to .8 inch; D = rainfall of 0 to .4 inch. Order of symbols corresponds to four equal periods beginning one week before planting and extending to one week before final harvest.

[3] Distribution and amount of rainfall within each period: a = excellent; b = good; c = fair; and d = poor. Symbols from left to right correspond to periods from first to fourth period.

APPENDIX TABLE 3. INCREASES IN YIELDS FROM IRRIGATION AS INFLUENCED BY THE AMOUNT AND DISTRIBUTION OF RAINFALL BY YEARS WITH ORGANIC MATERIALS ADDED

Crops and seasons[1]	Units	Increases in yields by years and amount and distribution of rainfall by periods				
Series A						
Beans, bush, total spring	Year	1938	1939	1940	1941	4-yr. av.
	Increase Bushels	−35	−21	106	130	45
	Increase Per cent	−20	−13	129	382	41
	Rainfall Amount[2]	AACB	ADAA	ADDA	CDDB	
	Rainfall Distribution[3]	abcb	accb	bcdb	cddb	
Broccoli, heads, fall	Year	1946	1947	1948		3-yr. av.
	Increase Pounds	124	1,619	76		606
	Increase Per cent	4	45	2		17
	Rainfall Amount	BCCA	CAAA	CBCA		
	Rainfall Distribution	bcca	ccbb	cccb		
Cabbage, heads, spring	Year	1942	1943	1944	1945	4-yr. av.
	Increase Pounds	8,794	2,829	12,084	−3,187	5,129
	Increase Per cent	38	18	212	−11	27
	Rainfall Amount	ACDA	ABBC	AAAD	AACA	
	Rainfall Distribution	ccdb	cccc	babc	aacb	
Lettuce, total fall	Year	1946	1947			2-yr. av.
	Increase Pounds	1,031	10,208			562
	Increase Per cent	7	117			49
	Rainfall Amount	ACCB	BDAA			
	Rainfall Distribution	bccb	bdba			
Potatoes, total spring	Year	1938	1939	1940	1941	4-yr. av.
	Increase Bushels	21	59	100	92	67
	Increase Per cent	12	49	60	48	41
	Rainfall Amount	CACB	CAAC	ABDA	BDBD	
	Rainfall Distribution	cacb	cbcc	abda	bdcd	
Sweetpotatoes, total summer and fall	Year	1943	1944	1945		3-yr. av.
	Increase Bushels	27	53	22		32
	Increase Per cent	7	13	6		8
	Rainfall Amount	BCBC	DCAA	BAAC		
	Rainfall Distribution	ccbb	ccaa	babc		

(*Continued*)

[1] All crops received 1,000 pounds of 6-10-4 fertilizer per acre.

[2] Rainfall by periods: A = rainfall above 1.2 inches per week; B = rainfall of .8 to 1.2 inches; C = rainfall of .4 to .8 inch; D = rainfall of 0 to .4 inch. Order of symbols corresponds to four equal periods beginning one week before planting and extending to one week before final harvest.

[3] Distribution and amount of rainfall within each period: a = excellent; b = good; c = fair; and d = poor. Symbols from left to right correspond to periods from first to fourth period.

APPENDIX TABLE 3. (*Continued*) INCREASES IN YIELDS FROM IRRIGATION AS INFLUENCED BY THE AMOUNT AND DISTRIBUTION OF RAINFALL BY YEARS WITH ORGANIC MATERIALS ADDED

Crops and seasons[1]	Units	Increases in yields by years and amount and distribution of rainfall by periods				
Series A						
Tendergreen, total fall	Year	1943	1944	1945		3-yr. av.
	Increase Pounds	10,010	10,578	5,241		8,610
	Increase Per cent	62	147	36		68
	Rainfall Amount[2]	DDAD	ACDD	BCCD		
	Rainfall Distribution[3]	ddcd	ccdd	bccd		
Turnip, total fall	Year	1938	1939	1940	1941	4-yr. av.
	Increase Pounds	1,740	13,565	11,117	1,914	7,084
	Increase Per cent	15	81	100	6	38
	Rainfall Amount	DDDB	BDDD	DDDB	CCCC	
	Rainfall Distribution	dddc	cddd	cddb	cccc	
Series B						
Beans, pole, total summer and fall	Year	1944	1946	1947	1948	4-yr. av.
	Increase Bushels	—16	60	—21	142	41
	Increase Per cent	—27	45	—7	49	21
	Rainfall Amount	AAAC	BCDA	BBDD	ACBC	
	Rainfall Distribution	abbc	bcdb	ccdd	bccd	
Corn, sweet, marketable, spring and summer	Year	1944	1946	1947	1948	4-yr. av.
	Increase Dozen ears	227	—147	160	786	256
	Increase Per cent	26	—24	14	118	31
	Rainfall Amount	ADCC	BCAA	BCCB	DDCA	
	Rainfall Distribution	bddc	bcaa	bccc	cddb	
Potatoes, total summer and fall	Year	1940	1941	1942	1943	4-yr. av.
	Increase Bushels	97	49	38	52	59
	Increase Per cent	462	272	33	116	118
	Rainfall Amount	BDDB	ACCD	ADAC	BCDD	
	Rainfall Distribution	cddb	bccc	bdbc	bbcc	
Tomatoes, total spring and summer	Year	1940	1941	1942	1943	4-yr. av.
	Increase Bushels	—142	—71	116	117	5
	Increase Per cent	—13	—8	22	30	1
	Rainfall Amount	ADAA	BDCA	DAAC	ACBA	
	Rainfall Distribution	adab	cdcb	dbbc	bcba	

[1] All crops received 1,000 pounds of 6-10-4 fertilizer per acre.

[2] Rainfall by periods: A = rainfall above 1.2 inches per week; B = rainfall of .8 to 1.2 inches; C = rainfall of .4 to .8 inch; D = rainfall of 0 to .4 inch. Order of symbols corresponds to four equal periods beginning one week before planting and extending to one week before final harvest.

[3] Distribution and amount of rainfall within each period: a = excellent; b = good; c = fair; and d = poor. Symbols from left to right correspond to periods from first to fourth period.

APPENDIX TABLE 4. YIELDS AND INCREASES IN YIELDS FROM IRRIGATION, FERTILIZERS, AND ORGANIC MATERIALS, SERIES A (YEARS OF HIGH RESPONSE)

Treatments		Yields and increases in yields per acre for years of high response											
		Beans, bush, total, spring, 1940			Broccoli, heads, fall, 1947			Cabbage, heads, spring, 1942			Lettuce, total, fall, 1947		
Fertilizer 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
500	0	5	29	24	1,453	2,035	582	0	8,538	8,538	461	4,710	4,249
500	Standard	76	135	59	4,384	5,446	1,062	13,920	16,461	2,541	7,264	12,211	4,947
	Increase from organic materials	71	106	35	2,931	3,411	480	13,920	7,923	—5,997	6,803	7,501	698
1,000	0	12	54	42	1,779	3,603	1,824	8,122	22,446	14,324	2,950	9,338	6,388
1,000	Standard	82	188	106	3,597	5,216	1,619	20,339	31,206	10,867	8,710	18,918	10,208
	Increase from organic materials	70	134	64	1,818	1,613	—205	12,217	8,760	—3,457	5,760	9,580	3,820
Increase from fertilizer without organic materials		7	25	18	326	1,568	1,242	8,122	13,908	5,786	2,489	4,628	2,139
Increase from fertilizer with organic materials		6	53	47	—787	—230	557	6,419	14,745	8,326	1,446	6,707	5,261

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 4. (*Continued*) YIELDS AND INCREASES IN YIELDS FROM IRRIGATION, FERTILIZERS, AND ORGANIC MATERIALS, SERIES A (FOR ALL YEARS)

Treatments		Yields and increases in yields per acre for all years											
Fertilizer 6-10-4 per acre	Organic materials[1]	Beans, bush, total, spring, 1938-41			Broccoli, heads, fall, 1946-48			Cabbage, heads, spring, 1942-45			Lettuce, total, fall, 1946-47		
		Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
500	0	45	64	19	1,298	1,606	308	651	3,336	2,685	1,610	3,078	1,468
500	Standard	85	120	35	3,244	3,370	126	9,630	11,736	2,106	6,890	10,845	3,955
	Increase from organic materials	40	56	16	1,946	1,764	—182	8,979	8,400	—579	5,280	7,767	2,487
1,000	0	82	91	9	1,745	2,408	663	6,488	9,091	2,603	5,683	7,280	1,597
1,000	Standard	111	156	45	3,555	4,161	606	15,449	20,281	4,832	11,430	17,050	5,620
	Increase from organic materials	29	65	36	1,810	1,753	—57	8,961	11,190	2,229	5,747	9,770	4,023
Increase from fertilizer without organic materials		37	27	—10	447	802	355	5,837	5,755	—82	4,073	4,202	129
Increase from fertilizer with organic materials		26	36	10	311	791	480	6,470	8,545	2,726	4,540	6,205	1,665

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 4. (*Continued*) YIELDS AND INCREASES IN YIELDS FROM IRRIGATION, FERTILIZERS, AND ORGANIC MATERIALS, SERIES A (YEARS OF HIGH RESPONSE)

Treatments		Yields and increases in yields per acre for years of high response											
		Beans, lima, total, summer, 1940			Corn, sweet, marketable, spring, summer, 1948			Onion, total, fall, winter, 1939-40			Squash, total, spring, summer, 1946-47		
Fertilizer 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
500	0	60	170	110	102	1,197	1,095	1,305	1,534	229	1,043	1,360	317
500	Standard	180	148	—32	1,600	2,784	1,184	5,538	4,836	—702	6,995	6,742	—253
	Increase from organic materials	120	—22	—142	1,498	1,587	89	4,233	3,302	—931	5,952	5,382	—570
1,000	0	143	187	44	1,357	3,136	1,779	2,631	3,653	1,022	3,840	3,789	—51
1,000	Standard	201	196	—5	3,834	4,813	979	7,577	6,730	—847	10,845	9,619	—1,226
	Increase from organic materials	58	9	—49	2,477	1,677	—800	4,946	3,077	—1,869	7,005	5,830	—1,175
Increase from fertilizer without organic materials		83	17	—66	1,255	1,939	684	1,326	2,119	793	2,797	2,429	—368
Increase from fertilizer with organic materials		21	48	27	2,234	2,029	—205	2,039	1,894	—145	3,850	2,877	—973

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 4. (*Continued*) YIELDS AND INCREASES IN YIELDS FROM IRRIGATION, FERTILIZERS, AND ORGANIC MATERIALS, SERIES A (FOR ALL YEARS)

Treatments		Yields and increases in yields per acre for all years											
		Beans, lima, total, summer, 1938-40			Corn, sweet, marketable, spring, summer, 1946-48			Onion, total, fall, winter, 1938-41			Squash, total, spring, summer, 1946-47		
Fertilizer 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
500	0	90	123	33	653	994	341	2,106	2,147	41	1,043	1,360	317
500	Standard	118	111	—7	3,951	4,489	538	6,171	6,040	—131	6,995	6,742	—253
	Increase from organic materials	28	—12	—40	3,298	3,495	197	4,065	3,893	—172	5,952	5,382	—570
1,000	0	126	131	5	2,656	3,416	760	3,295	3,822	527	3,840	3,789	—51
1,000	Standard	125	133	8	5,617	5,734	117	7,949	7,957	8	10,845	9,619	—1,226
	Increase from organic materials	—1	2	3	2,961	2,318	—643	4,654	4,135	—519	7,005	5,830	—1,175
Increase from fertilizer without organic materials		36	8	—28	2,003	2,422	419	1,189	1,675	486	2,797	2,429	—368
Increase from fertilizer with organic materials		7	22	15	1,666	1,245	—421	1,778	1,917	139	3,850	2,877	—973

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 4. (*Continued*) YIELDS AND INCREASES IN YIELDS FROM IRRIGATION, FERTILIZERS, AND ORGANIC MATERIALS, SERIES A (YEARS OF HIGH RESPONSE)

Treatments		Yields and increases in yields per acre for years of high response											
		Potatoes, total, spring, 1941			Sweetpotatoes, total, summer, fall, 1944			Tendergreen, total, fall, 1943			Turnip, total, fall, 1939		
Fertilizer 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
500	0	51	88	37	230	265	35	4,525	8,915	4,390	10,573	15,956	5,383
500	Standard	157	195	38	323	409	86	12,141	18,515	6,374	16,218	24,597	8,379
	Increase from organic materials	106	107	1	93	144	51	7,616	9,600	1,984	5,645	8,641	2,996
1,000	0	101	167	66	287	385	98	8,781	14,342	5,561	14,153	21,233	7,080
1,000	Standard	191	283	92	395	448	53	16,108	26,118	10,010	16,798	30,363	13,565
	Increase from organic materials	90	116	26	108	63	—45	7,327	11,776	4,449	2,645	9,130	6,485
Increase from fertilizer without organic materials		50	79	29	57	120	63	4,256	5,427	1,171	3,580	5,277	1,697
Increase from fertilizer with organic materials		34	88	54	72	39	—33	3,967	7,603	3,636	580	5,766	5,186

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 4. (*Continued*) YIELDS AND INCREASES IN YIELDS FROM IRRIGATION, FERTILIZERS, AND ORGANIC MATERIALS, SERIES A (FOR ALL YEARS)

Treatments		Yields and increases in yields per acre for all years											
		Potatoes, total, spring, 1938-41			Sweetpotatoes, total, summer, fall, 1943-45			Tendergreen, total, fall, 1943-45			Turnip, total, fall, 1938-41		
Fertilizer 6-10-4 per acre	Organic materials[1]	Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
500	0	80	82	2	232	277	45	4,139	8,098	3,959	9,498	12,981	3,483
500	Standard	137	176	39	352	399	47	9,783	14,701	4,918	18,145	21,983	3,838
	Increase from organic materials	57	94	37	120	122	2	5,644	6,603	959	8,647	9,002	355
1,000	0	115	130	15	309	373	64	7,358	13,494	6,136	12,962	18,615	5,653
1,000	Standard	162	229	67	383	415	32	12,570	21,180	8,610	18,432	25,516	7,084
	Increase from organic materials	47	99	52	74	42	—32	5,212	7,686	2,474	5,470	6,901	1,431
Increase from fertilizer without organic materials		35	48	13	77	96	19	3,219	5,396	2,177	3,464	5,634	2,170
Increase from fertilizer with organic materials		25	53	28	31	16	—15	2,787	6,479	3,692	287	3,533	3,246

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 5. YIELDS AND INCREASES IN YIELDS FROM IRRIGATION AND DIFFERENT ORGANIC MATERIALS FOR YEARS OF HIGH RESPONSE AND FOR ALL YEARS, SERIES B

Treatments		Yields and increases in yields per acre											
		Beans, pole, total, summer, fall			Corn, sweet, marketable ears, spring, summer			Potatoes, total summer, fall			Tomatoes, total, spring, summer		
Fertilizer 6-10-4 per acre	Manures[1]	Without irrigation	With irrigation[2]	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation	Without irrigation	With irrigation	Increase from irrigation
Lb.		*Bu.*	*Bu.*	*Bu.*	*Doz.*	*Doz.*	*Doz.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
							For years of high response						
			1948			1948			1940			1943	
1,000	0	168	295	127	400	813	413	28	76	48	140	300	160
1,000	Animal manure	287	429	142	667	1,453	786	21	118	97	396	513	117
	Increase from animal manure	119	134	15	267	640	373	—7	42	49	256	213	—43
1,000	0	168	295	127	400	813	413	28	76	48	140	300	160
1,000	Rye	206	320	114	733	1,240	507	11	82	71	258	280	22
	Increase from rye	38	25	—13	333	427	94	—17	6	23	118	—20	—138
							Average for all years						
			1944, 1946-48			1944, 1946-48			1940-43			1940-43	
1,000	0	108	170	62	413	630	217	37	64	27	369	427	58
1,000	Animal manure	195	236	41	827	1,083	256	50	109	59	709	714	5
	Increase from animal manure	87	66	—21	414	453	39	13	45	32	340	287	—53
1,000	0	108	170	62	413	630	217	37	64	27	369	427	58
1,000	Rye	145	199	54	700	817	117	40	76	36	461	470	9
	Increase from rye	37	29	—8	287	187	—100	3	12	9	92	43	—49

[1] Animal manure was applied at the rate of 12 tons per acre per year. Rye was grown and turned under.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

APPENDIX TABLE 6. YIELDS OF DIFFERENT VEGETABLE CROPS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND RATES OF FERTILIZER, SERIES A

Treatments			Yields per acre for years of high response and average yields for all years									
			Beans, lima		Beans, snap		Broccoli		Cabbage			
Fertilizer 6-10-4 per acre	Organic materials[1]	Irrigation per week[2]	1940 Total	(3-yr. av.) 1938-40 Total	(2-yr. av.) 1940-41 Total	(4-yr. av.) 1938-41 Total	1947 Heads	(3-yr. av.) 1946-48 Heads	(2-yr. av.) 1942, 1944 Heads	(2-yr. av.) 1942, 1944 Total	(4-yr. av.) 1942-45 Heads	(4-yr. av.) 1942-45 Total
Lb.		*In.*	*Bu.*	*Lb.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
0	0	0	----	122	0	19	307	160	0	326	0	398
500	0	0	60	90	2	45	1,453	1,298	0	6,083	651	6,735
500	0	1	170	123	40	64	2,035	1,606	4,682	11,453	3,336	9,222
500	Standard	0	180	118	53	85	4,384	3,244	6,960	12,678	9,630	14,841
500	Standard	1	148	111	128	120	5,446	3,370	12,467	18,320	11,736	17,495
1,000	0	0	143	126	11	82	1,779	1,745	4,061	10,601	6,488	12,666
1,000	0	1	187	131	58	91	3,603	2,408	12,316	16,585	9,091	14,219
1,000	Standard	0	201	125	58	111	3,597	3,555	10,196	14,358	15,449	18,728
1,000	Standard	1	196	133	176	156	5,216	4,161	21,824	24,797	20,281	23,857
1,000	Vetch	1	258	162	214	196	4,038	2,848	15,174	18,867	10,382	16,719
1,000	Cowpeas	1	----	-----	78	116	5,267	3,358	17,993	22,630	15,387	20,285
1,000[3]	Standard	1	128	126	88	87	3,526	2,078	896	9,273	2,365	10,048
1,000[4]	0	1	----	-----	-----	-----	3,642	3,189	5,862	13,984	13,252	17,179

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] Nitrogen was not included in the fertilizer for this treatment.
[4] Extra nitrogen, 40 pounds per acre, was applied to this treatment.

APPENDIX TABLE 6. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND RATES OF FERTILIZER, SERIES A

Treatments			Yields per acre for years of high response and average yields for all years									
			Sweet corn				Lettuce				Onion	
Fertilizer 6-10-4 per acre	Organic materials[1]	Irrigation per week[2]	1948		(3-yr. av.) 1946-1948		1947		(2-yr. av.) 1946-1947		(2-yr. av.) 1939-40	(4-yr. av.) 1938-41
			Mkt.	Total	Mkt.	Total	Heads	Total	Heads	Total	Total	Total
Lb.		*In.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
0	0	0	0	1,549	0	692	0	13	0	7	248	406
500	0	0	102	3,725	653	3,245	0	461	0	1,610	1,305	2,106
500	0	1	1,197	4,090	994	3,292	269	4,710	135	3,078	1,534	2,147
500	Standard	0	1,600	4,902	3,951	6,547	723	7,264	467	6,890	5,538	6,171
500	Standard	1	2,784	6,010	4,489	7,365	2,470	12,211	1,402	10,845	4,836	6,040
1,000	0	0	1,357	4,442	2,656	5,427	0	2,950	343	5,683	2,631	3,295
1,000	0	1	3,136	6,797	3,416	6,003	1,670	9,338	992	7,280	3,653	3,822
1,000	Standard	0	3,834	7,782	5,617	8,881	1,427	8,710	1,146	11,430	7,577	7,949
1,000	Standard	1	4,813	7,866	5,734	9,016	6,016	18,918	3,863	17,050	6,730	7,957
1,000	Vetch	1	4,000	8,147	5,722	9,320	1,779	11,942	1,031	9,542	3,055	4,316
1,000	Cowpeas	1	3,814	7,296	4,514	7,237	1,728	10,630	1,290	10,637	4,813	5,116
1,000[3]	Standard	1	1,274	3,942	2,112	4,220	2,598	10,682	1,395	8,045	3,195	4,252
1,000[4]	0	1	4,864	9,254	5,227	8,743	1,606	9,722	1,146	11,744	———	———

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] Nitrogen was not included in the fertilizer for this treatment.
[4] Extra nitrogen, 40 pounds per acre, was applied to this treatment.

APPENDIX TABLE 6. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND RATES OF FERTILIZER, SERIES A

Treatments			Yields per acre for years of high response and average yields for all years								
			Potatoes				Squash	Sweetpotatoes			
Fertilizer 6-10-4 per acre	Organic materials[1]	Irrigation per week[2]	(2-yr. av.) 1940-1941		(4-yr. av.) 1938-1941		(2-yr. av.) 1946-1947	(2-yr. av.) 1944-1945		(3-yr. av.) 1943-1945	
			Mkt.	Total	Mkt.	Total	Total	Mkt.	Total	Mkt.	Total
Lb.		*In.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Lb.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
0	0	0	0	1	18	28	0	40	69	57	94
500	0	0	23	44	49	80	1,043	162	212	189	232
500	0	1	46	66	50	82	1,360	195	243	229	277
500	Standard	0	115	147	100	137	6,995	260	321	279	352
500	Standard	1	166	197	134	176	6,742	346	398	348	399
1,000	0	0	57	86	75	115	3,840	230	281	253	309
1,000	0	1	96	125	90	130	3,789	316	373	320	373
1,000	Standard	0	147	178	125	162	10,845	331	386	317	383
1,000	Standard	1	242	274	186	229	9,619	383	424	364	415
1,000	Vetch	1	247	265	247	265	5,411	375	441	345	416
1,000	Cowpeas	1	144	176	150	189	3,533	342	384	322	372
1,000[3]	Standard	1	94	123	90	121	2,327	238	276	262	317
1,000[4]	0	1	----	----	----	----	9,568	342	389	329	373

(*Continued*)

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] Nitrogen was not included in the fertilizer for this treatment.
[4] Extra nitrogen, 40 pounds per acre, was applied to this treatment.

APPENDIX TABLE 6. (*Continued*) YIELDS OF DIFFERENT VEGETABLE CROPS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND RATES OF FERTILIZER, SERIES A

Treatments			Yields per acre for years of high response and average yields for all years					
			Tendergreen		Turnip			
Fertilizer 6-10-4 per acre	Organic materials[1]	Irrigation per week[2]	(2-yr. av.) 1943-1944 Total	(3-yr. av.) 1943-1945 Total	(2-yr. av.) 1939-1940 Roots	(2-yr. av.) 1939-1940 Total	(4-yr. av.) 1938-1941 Roots	(4-yr. av.) 1938-1941 Total
Lb.		*In.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
0	0	0	52	69	0	0	98	368
500	0	0	3,194	4,139	3,108	6,438	5,293	9,498
500	0	1	7,242	8,098	6,737	12,166	7,538	12,981
500	Standard	0	9,309	9,783	6,230	13,451	9,446	18,145
500	Standard	1	15,149	14,701	11,016	21,630	12,023	21,983
1,000	0	0	6,112	7,358	3,954	8,531	6,608	12,962
1,000	0	1	12,599	13,494	8,346	17,824	9,588	18,615
1,000	Standard	0	11,648	12,570	5,908	13,967	8,647	18,432
1,000	Standard	1	21,942	21,180	12,408	26,308	12,441	25,516
1,000	Vetch	1	16,557	17,287	10,340	22,193	11,872	23,976
1,000	Cowpeas	1	19,236	17,507	10,087	21,113	10,452	22,255
1,000[3]	Standard	1	4,874	5,025	6,593	13,271	7,438	13,888
1,000[4]	0	1	19,027	18,827	----------	----------	----------	----------

[1] Two tons per acre of dry lespedeza sericea was applied in winter and 6 tons of green crotalaria in summer.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] Nitrogen was not included in the fertilizer for this treatment.
[4] Extra nitrogen, 40 pounds per acre, was applied to this treatment.

APPENDIX TABLE 7. YIELDS OF DIFFERENT VEGETABLE CROPS FROM USE OF IRRIGATION, ORGANIC MATERIALS, AND RATES OF FERTILIZER, SERIES B

Treatments					Yields per acre for years of high response and average of all years											
Fertilizer 6-10-4 per acre	Manure			Irrigation per week[2]	Beans, pole		Corn, sweet		Potatoes				Tomatoes			
	Animal per acre	Green[1]			(2-yr. av.) 1946, 1948 Total	(4-yr. av.) 1944-48 Total	(2-yr. av.) 1944, 1948 Mkt. ears	(4-yr. av.) 1944, 1946-48 Mkt. ears	(2-yr. av.) 1940, 1941 Mkt.	Total	(4-yr. av.) 1940-43 Mkt.	Total	(2-yr. av.) 1942, 1943 Mkt.	Total	(4-yr. av.) 1940-43 Mkt.	Total
		Legume	Non-legume													
Pounds	*Tons*			*Inches*	*Bu.*	*Bu.*	*Doz.*	*Doz.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
0	0	0	0	0	0	10	0	0	2	7	3	10	11	20	49	76
1,000	0	0	0	0	120	108	353	413	14	22	27	37	134	218	246	369
1,000	0	0	0	1	217	170	660	630	43	56	50	64	187	301	284	427
1,000	12	0	0	0	210	195	773	827	12	19	40	50	333	465	507	709
1,000	12	0	0	1	311	236	1,280	1,083	71	92	87	109	405	582	493	714
1,000	0	Vetch	0	0	122	123	685	525	13	20	30	41	167	252	322	467
1,000	0	Vetch	0	1	202	154	1,080	653	49	65	59	76	203	346	354	550
1,000	0	0	Rye	0	151	145	653	700	9	18	28	40	195	315	307	461
1,000	0	0	Rye	1	265	199	927	817	49	58	62	76	247	370	320	470
1,000	12	Vetch	0	0	192	147	940	937	15	24	39	49	326	476	485	697
1,000	12	Vetch	0	1	268	202	1,586	1,190	83	97	87	103	361	543	538	785
1,000[3]	12	Vetch	0	1	295	216	1,520	1,220	81	97	86	104	407	616	571	814
1,000	6	Vetch	0	1	253	202	1,407	1,083	56	71	69	89	350	509	509	722
1,000	6	0	Rye	1	285	214	1,247	1,017	60	71	68	82	338	472	481	652
1,500	12	Vetch	0	1	305	202	1,493	1,376	99	113	101	118	367	566	513	777
2,000	12	Vetch	0	1	312	204	1,486	1,333	96	109	95	112	380	554	521	764

[1] Green manure crops were grown and turned under.
[2] One inch of water per week was applied when rainfall during previous week had not supplied that amount.
[3] Minor elements were applied to all treatments except this one.

APPENDIX TABLE 8. PLANTING AND HARVESTING DATES AND AVERAGE AMOUNT OF IRRIGATION PER YEAR GIVEN EACH CROP FOR THE SELECTED YEARS OF HIGH RESPONSE AND FOR ALL YEARS

Crops	Seasons	Planting dates	Harvesting dates	Years and acre inches of water applied			
				Years of high response		All years	
				Years	Acre inches applied	Years	Acre inches applied
Series A							
Beans, lima	Summer	June 19 to 24	Aug. 16 to Sept. 18	1940	5.00	1938-40	3.67
Beans, bush	Spring	Mar. 20 to May 9	May 23 to July 1	1939-41	2.50	1938-41	3.50
Broccoli	Fall	Aug. 20 to 30	Nov. 20 to Feb. 20	1947	4.00	1946-48	3.33
Cabbage	Spring	Feb. 20 to Mar. 10	June 1 to 20	1942, 1944	6.00	1942-45	5.50
Corn, sweet	Spring, summer	Apr. 5 to May 22	June 26 to July 13	1948	6.00	1946-48	5.00
Lettuce	Fall	Sept. 12 to 18	Nov. 15 to Dec. 18	1947	3.00	1946-47	3.00
Onion	Fall, winter	Sept. 4 to Oct. 14	Feb. 7 to May 2	1939-40	8.50	1938-41	9.25
Potatoes	Spring	Feb. 22 to Mar. 13	June 7 to 24	1940-41	5.00	1938-41	4.25
Squash	Spring, summer	Apr. 21 to May 17	June 10 to July 22	1946-47	3.00	1946-47	3.00
Sweetpotatoes	Summer, fall	Apr. 30 to May 16	Oct. 1 to 10	1944-45	7.50	1943-45	8.67
Tendergreen	Fall	Sept. 12 to 21	Oct. 19 to Dec. 10	1943-44	5.50	1943-45	4.33
Turnip	Fall	Sept. 12 to Oct. 3	Nov. 6 to Dec. 1	1939-40	5.50	1938-41	6.00
Series B							
Beans, pole	Summer, fall	July 14 to Aug. 10	Sept. 12 to Nov. 10	1946, 1948	5.00	1944, 1946-48	4.25
Corn, sweet	Spring, summer	Apr. 2 to May 2	June 18 to July 21	1944, 1948	6.75	1944, 1946-48	6.50
Potatoes	Summer, fall	Aug. 11 to 20	Oct. 31 to Nov. 19	1940-41	4.50	1940-43	4.50
Tomatoes	Spring, summer	Mar. 28 to Apr. 24	June 26 to Aug. 9	1942-43	3.50	1940-43	3.50
Average					5.08		4.89

APPENDIX TABLE 9. GROSS VALUES AND VALUES ABOVE COST OF PRACTICES FROM YIELD INCREASES RESULTING FROM USE OF IRRIGATION AND ORGANIC MATERIALS SEPARATELY AND IN COMBINATION, SERIES A AND B, YEARS OF HIGH RESPONSE

Crops[1]	Gross values of increases per acre[2]					Values of increases above cost of practices per acre				
	From irrigation[3]		From organic materials		From both irrigation and organic materials	From irrigation		From organic materials		From both irrigation and organic materials
	Without organic materials[4]	With organic materials	Without irrigation	With irrigation		Without organic materials	With organic materials	Without irrigation	With irrigation	
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Series A										
Beans, lima	105.60	—12.00	139.20	21.60	127.20	77.60	—40.00	114.20	—3.40	74.20
Beans, snap	112.80	283.20	112.80	283.20	396.00	98.80	269.20	87.80	258.20	357.00
Broccoli	182.40	161.90	181.80	161.30	343.70	160.00	139.50	156.80	136.30	296.30
Cabbage	165.10	232.56	122.70	190.16	355.26	131.50	198.96	97.70	165.16	296.66
Corn, sweet	80.10	24.00	120.00	63.90	144.00	46.50	—9.60	95.00	38.90	85.40
Lettuce	255.52	408.32	230.40	283.20	638.72	238.72	391.52	205.40	358.20	596.92
Onion	61.32	—50.82	296.76	184.62	245.94	13.72	—98.42	271.76	159.62	173.34
Potatoes	70.35	174.30	156.45	260.40	330.75	42.35	146.30	131.45	235.40	277.75
Squash	—1.53	—36.78	210.15	174.90	173.37	—18.33	—53.58	185.15	149.90	131.57
Sweetpotatoes	191.25	141.25	228.75	178.75	370.00	149.25	99.25	203.75	153.75	303.00
Tendergreen	128.46	158.20	83.08	112.82	241.28	111.66	141.40	58.08	87.82	199.48
Turnip	185.86	246.82	108.72	169.68	355.54	155.06	216.02	83.72	144.68	299.74
Series B										
Beans, pole	232.80	242.40	216.00	225.60	458.40	204.80	214.40	191.00	200.60	405.40
Corn, sweet	92.10	152.10	126.00	186.00	278.10	54.30	114.30	101.00	161.00	215.30
Potatoes	54.60	101.85	2.10	49.35	103.95	29.40	76.65	—22.90	24.35	53.75
Tomatoes	106.00	144.00	398.00	436.00	542.00	86.40	124.40	373.00	411.00	497.40
Average	126.42	148.20	170.81	192.59	319.01	98.86	120.64	145.81	167.59	266.45

[1] All crops received 1,000 pounds of 6-10-4 per acre.

[2] Values were based on estimated prices considered reasonably conservative. The value of No. 2 grade potatoes and sweetpotatoes was at one-half that of No. 1 grade.

[3] One inch of water per week was applied when rainfall during previous week had not supplied that amount.

[4] In series A, 2 tons per acre of dry lespedeza was applied in winter and 6 tons of green crotalaria in summer; in series B, 12 tons per acre of animal manure was applied in late winter.

APPENDIX TABLE 10. GROSS VALUES AND VALUES ABOVE COST OF PRACTICES FROM YIELD INCREASES RESULTING FROM USE OF IRRIGATION AND ORGANIC MATERIALS SEPARATELY AND IN COMBINATION, SERIES A AND B, ALL YEARS

Crops[1]	Gross values of increases per acre[2]					Values of increases above cost of practices per acre				
	From irrigation[3]		From organic materials		From both irrigation and organic materials	From irrigation		From organic materials		From both irrigation and organic materials
	Without organic materials[4]	With organic materials	Without irrigation	With irrigation		Without organic materials	With organic materials	Without irrigation	With irrigation	
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Series A										
Beans, lima	12.00	19.20	—2.40	4.80	16.80	—8.50	—1.30	—27.40	—20.20	—28.70
Beans, snap	21.60	108.00	69.60	156.00	177.60	2.00	88.40	44.60	131.00	133.00
Broccoli	66.30	60.60	181.00	175.30	241.60	47.65	41.95	156.00	150.30	197.95
Cabbage	52.06	96.64	179.22	223.80	275.86	13.26	57.84	154.22	198.80	212.06
Corn, sweet	29.40	3.00	114.60	88.20	117.60	1.40	—25.00	89.60	63.20	64.60
Lettuce	63.88	224.80	229.88	390.80	454.68	47.08	208.00	204.88	365.80	412.88
Onion	31.62	.48	279.24	248.10	279.72	—20.18	—51.32	254.24	223.10	202.92
Potatoes	27.30	105.00	88.30	165.90	193.30	3.50	81.20	63.20	140.90	144.40
Squash	—1.53	—36.78	210.15	174.90	173.37	—18.33	—53.58	185.15	149.90	131.57
Sweetpotatoes	136.25	137.50	118.75	120.00	256.25	87.75	89.00	93.75	95.00	182.75
Tendergreen	122.72	172.20	104.24	153.72	276.44	94.72	144.20	79.24	128.72	223.44
Turnip	113.06	141.68	109.40	138.02	251.08	79.46	108.08	84.40	113.02	192.48
Series B										
Beans, pole	148.80	98.40	208.80	158.40	307.20	125.00	74.60	183.80	133.40	258.40
Corn, sweet	65.10	76.80	124.20	135.90	201.00	28.70	40.40	99.20	110.90	139.60
Potatoes	43.05	82.95	26.25	66.15	109.20	17.85	57.75	1.25	41.15	59.00
Tomatoes	76.00	—28.00	522.00	418.00	494.00	56.40	—47.60	497.00	393.00	449.40
Average	62.98	78.90	160.20	176.12	239.10	34.86	50.79	135.19	151.12	185.98

[1] All crops received 1,000 pounds of 6-10-4 per acre.

[2] Values were based on estimated prices considered reasonably conservative. The value of No. 2 grade potatoes and sweetpotatoes was at one-half that of No. 1 grade.

[3] One inch of water per week was applied when rainfall during the previous week had not supplied that amount.

[4] In series A, 2 tons per acre of dry lespedeza was applied in winter and 6 tons of green crotalaria in summer; in series B, 12 tons per acre of animal manure was applied in late winter.

APPENDIX TABLE 11. YIELDS OF DIFFERENT COVER CROPS GROWN AND TURNED, SERIES A

Treatments				Yields per acre by years										
No.	Fertilizer per acre[1]	Organic materials[2]	Irrigation[1]	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
	Lb.		*In.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
10	1,000	Vetch	1	[3]	10,208	6,470	11,661	6,400	10,507	3,677	14,413	12,000[4]	12,000[4]	12,000[4]
11	1,000	Cowpeas	1	[3]	8,269	9,600	19,750	21,098	18,090	17,360	12,000[4]	12,000[4]	12,000[4]	12,000[4]

[1] Irrigation and fertilizer were applied to vegetable crops and not to cover crops.
[2] Vetch and cowpeas were grown in plots and turned.
[3] Cover crops were grown and turned without record of weights being taken.
[4] Tonnage low due to short growing period between truck crops, enough green manure added to give 6 tons.

APPENDIX TABLE 12. YIELDS OF DIFFERENT COVER CROPS GROWN AND TURNED, SERIES B

Treatments					Yields per acre by years								
No.	Fertilizer per acre[1] (6-10-4)	Manure		Irrigation[1]	1940[3]	1941	1942	1943	1944	1945	1946[4]	1947	1948
		Animal	Green[2]										
	Lb.	*Tons*		*In.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
6	1,000	0	Vetch	0	20,000	10,016	8,800	9,360	8,960	4,829	8,944	11,616	5,082
7	1,000	0	Vetch	1	20,000	12,352	3,680	8,480	9,920	4,144	6,256	10,464	6,762
8	1,000	0	Rye	0	6,000	6,950	8,634	11,680	10,720	14,016	17,200	12,800	13,680
9	1,000	0	Rye	1	6,000	6,969	14,432	9,520	9,040	11,722	14,304	9,184	12,640
10	1,000	12	Vetch	0	20,000	12,448	17,840	11,360	14,880	8,528	10,512	19,872	13,562
11	1,000	12	Vetch	1	20,000	16,681	11,843	9,600	10,160	8,346	12,144	23,498	14,522
12[5]	1,000	12	Vetch	1	20,000	14,166	13,440	10,960	14,960	8,077	13,680	19,923	12,320
13	1,000	6	Vetch	1	20,000	15,638	10,000	8,240	13,360	5,850	12,688	15,536	11,882
14	1,000	6	Rye	1	6,000	7,232	12,378	10,640	11,440	14,720	21,856	15,232	17,040
15	1,500	12	Vetch	1	20,000	16,156	12,800	9,440	16,400	7,805	14,832	21,146	14,358
16	2,000	12	Vetch	1	20,000	14,105	13,840	10,640	16,160	6,806	12,672	22,768	14,042

[1] Irrigation and fertilizer were applied to vegetable crops and not to cover crops.
[2] Vetch and rye were grown in plots and turned.
[3] In 1940 green manures were introduced.
[4] In 1946 blue lupine was grown instead of vetch.
[5] Minor elements were applied to all treatments except this one.